“The experiences I give them, that is going to be their opinion” : Formative assessment through dialogue in Technology Education

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Abstract

The purpose of the formative assessment is for the teacher to recognise the student's learning and guide the student to the next step in their learning. This study focuses on Interactive Formative Assessment (IFA), which is formative assessment through dialogue. IFA through dialogue is especially critical in a subject like Technology Education (TE) where students design and develop products based on a given design brief. As every student is developing something independently, formal whole-class test may not be effective for formative assessment. Formative assessment in TE is carried out mainly through dialogue. However, to participate in a dialogue, the teacher needs to plan open, high-cognitive questions that can encourage dialogue. Technology Observation and Conversation Framework (TOCF) (Fox-Turnbull, 2018) was identified as a framework of high-cognitive questions specially designed for a technology classroom. In this study, the TOCF was modified for use as a formative assessment tool and is called Questioning Framework for Technology - Primary (QFT-P). This study, thus, contributes to the research in formative assessment and dialogue in TE in primary schools - two areas that have limited research to date. This research addresses the research gap in the process of IFA in TE, teacher beliefs and knowledge for conducting IFA, and student learning through participating in the IFA dialogue.

In this qualitative, pragmatic, design-based research, the QFT-P was aligned with the New Zealand curriculum and provided to two primary teachers teaching Year 5-6 (ages 9-10). Design-based research has dual aims - implementing a resource in a naturalistic environment and understanding the theory behind the implementation process. In this research, 175 hours of classroom observations and 35 hours of audio-recording of teacher-student dialogue were the main sources of data. Interviews, video-recording,and photographs of classroom artefacts and student work were other sources of data. Teacher's experiences with using the QFT-P dictated the iterations of the formative assessment tool.

The findings showed that the teachers used the QFT-P as a formative assessment tool and were able to have a deep and rich dialogue with the students. Through the dialogue, teachers were able to recognise student learning and guide them to the next step in their learning. Based on analysis of dialogue in the classroom, the existing model of IFA was expanded by the addition of two steps - Student action and Teacher follow-up and conceptualised as a spiral. IFA is recognised to be a complex process due to the teacher managing the spiral for multiple students at the same time. Teachers showed implicit knowledge about TE that they were not always able to translate into teaching TE. Teachers' beliefs about the importance of student's voice and teachers' content knowledge of TE were important to conduct an effective IFA. When participating in IFA, students showed concrete learning in many of the curriculum objectives and teacher's priority objectives. However, students did not always implement their feedback and it was seen in this study that if the feedback was not implemented within the next lesson, there was a loss of opportunity for the associated learning.

This thesis brings new insights in the field of IFA and formative assessment in TE and offers a formative assessment tool in the form of the QFT-P for primary, technology teachers.

Notes:

- *Quotations used in this thesis have been modified removing pauses, grammatical errors, rephrasing.*
- *This thesis has been written and compiled in LaTeX. Spacing between paragraphs, image positions are determined by LaTeX.*
- *In the PDF of the document, hovering over any abbreviation will show you the full form of the abbreviation. Everything in blue is a working link.*

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A thesis is a long endeavour and uncountable people, some whose names you never knew, spark a thought that makes it into the thesis. I have had many such encounters - one at a Halloween party, one over a zoom call while discussing some other thesis, one while selling something online. I will not remember all such encounters and names of all those people. But I acknowledge the serendipity that led to these fleeting encounters and their impact on the thesis.

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Acronyms

AO Achievement Objectives

BD Brief Development

CT Characteristics of Technology

CTO Characteristics of Technological Outcome

DBR Design-Based Research

ESU Elicitation-Student response-Use

IFA Interactive Formative Assessment

IoP Indicators of Progression

IRF Initiation-Response-Feedback

NCEA National Certificate of Educational Achievements

NMSSA National Monitoring Study of Student Achievement New Zealand

NT Nature of Technology

NZ New Zealand

NZC New Zealand Curriculum

NZCER New Zealand Centre for Educational Research

ODE Outcome Development and Evaluation

PBL Project-Based Learning

PCK Pedagogical Content Knowledge

PD Professional Development

PP Planning for Practice

QFT-P Questioning Framework for Technology - Primary

STEAM Science, Technology, Engineering, Arts, and Maths

STEM Science, Technology, Engineering, and Maths

TE Technology Education

TK Technological knowledge

TM Technological Modelling

TOCF Technology Observation and Conversation Framework

Tp Technological products

TP Technological Practice

USA United States of America

Chapter 1

Introduction

> There is, I think, no point in the philosophy of progressive education which is sounder than its emphasis upon the importance of the participation of the learner in the formation of the purposes which direct his activities in the learning process, just as there is no defect in traditional education greater than its failure to secure the active co-operation of the pupil in construction of the purposes involved in his studying (Dewey, 1997, p. 46-49).

When Professor Neil Mercer tweeted his criticism of United Kingdom's Education Minister, Gavin Williamson's belief about the superiority of the "traditional teacher-led lessons with children seated facing the expert at the front of the class" (Mercer, 2021) in the year 2021, they echoed John Dewey's argument made in his book 'Experience and Education', written in 1938, 83 years ago. Dewey strongly argued for the right of the learner to participate in their learning, to learn based on their own experience. However, the students' learning in the classroom through their experience need not come by demolishing every principle of organization of a traditional classroom (Dewey, 1997).

Dewey urged that the "either-or" argument for or against traditional schooling is likely to throw out the baby with the bath-water. In seeking to reject a top-down control in schools, progressive schools are likely to reject all forms of control and reject any authority source. Dewey was not against the presence or role of a teacher in the classroom. He felt ignoring the teacher as part of the learning community in the classroom was the same issue as not allowing students to participate in their learning. His argument supported a different role for the teacher - where the teacher organizes experiences that are conducive to students' learning.

The world view of this thesis aligns with Dewey's belief of the role of student and teacher in the learning process in a classroom. The teacher is a core part of the learning community, just as the student. Being a more mature and relative expert, the teacher has an additional responsibility to guide students on their learning journey. The experiences the teacher provides in the classroom will be what the students will make sense of and integrate into their learning.

How students experience what is happening in the classroom is different for every student. Students have a “hidden life” (Nuthall, 2007) in the classroom of which most teachers are unaware. Students also come with different experiences from their life at home, their communities, and their social circle. Their varied life in and out of the classroom is why students experience the classroom differently than the teacher. These different experiences lead to different learning for every student, and a way to recognise this learning is to ask questions.

Asking students about their learning is often a part of formative assessment. The teacher elicits information from the student and then offers guidance on what the student can do next to progress their learning. Formative assessment is, thus, a vital part of the learning process. Asking questions is a crucial part of formative assessment. Elicitation of student learning is the first step. The next step is to listen to the students and interpret what they have learnt. The final step of formative assessment is for the teacher to use the information that they have gained from the student to help them progress on their learning path. Understanding the student learning may take multiple back-and-forth interactions between the teacher and the student - a dialogue where both the participants are learning. The teacher is learning about what sense the student has made of their experiences, and the student is learning ways of clearly articulating their experiences and the sense they make of them. Dialogue is essential for this second step. A formative assessment carried through dialogue between teacher and student(s) is called IFA (Cowie & Bell, 1999) and is the focus in this study.

When a teacher in this study asked the students, “How can working in a team help you make a better product?” in a whole-class discussion, she expected to hear answers about teamwork and collaboration. Instead, she heard students who worked alone defended independent work and students who worked with other friends defended group work. Inadvertently, she had set up students for different experiences in the classroom by offering them a choice on how they wanted to work on their project. The students expressed their learning based on their different experiences. The teacher realised that the experiences that she gave the students, is what the students learnt. She was able to offer a different experience in the next unit based on this knowledge. This brief incident highlights the essential role of formative assessment and the imperative for teachers to have a dialogue with students. Consequently, this study aims to delve into the formative assessment dialogue and the influence of the process of formative assessment on the student work.

1.1 Context of study - New Zealand

This study is qualitative and based on research in two primary classrooms in New Zealand (NZ). NZ is an island in the south Pacific ocean with a population of around five million (as of 2022). NZ education system has three levels - early childhood education from birth to school entry age, primary and secondary education from 5-19 years of age, and further education for higher and vocational education (Ministry of Education, 2021). Compulsory schooling is for ages 6-16. Primary school covers Year 1 to Year 8 (around ages 5-12) and secondary school covers Year 9 to Year 13 (around ages 13-17) (ibid). Students can go to schools where the medium of instruction is English or Maori. Most schools are funded by the government and are free to attend. Some schools can be state-integrated with a particular religious or philosophical character and some are private (ibid). State-integrated and private schools are not free and there is a tuition fee to attend these schools. This study was carried out at two government primary schools where the medium of instruction is English.

In primary and secondary schools, eight learning areas are specified - English, arts, health and physical education, learning languages, mathematics and statistics, science, social sciences, and TE (Ministry of Education, 2018a). The learning area in focus in this study is TE. In addition to the learning areas, the New Zealand Curriculum (NZC) specifies five key competencies that are "key to learning in every learning area" (Ministry of Education, 2018a, p. 12). The five key competencies are thinking, using language, symbols and texts, managing self, relating to others, and participating and contributing. For every learning area, the achievement objectives are set at eight levels of learning. Achievement Objectives (AO) specify the learning processes, knowledge, and skills for a specific level of learning (Ministry of Education, 2018a). Schools are encouraged to build their curriculum considering the AOs they will meet but not at the expense of students' ultimate learning success (ibid). The NZC provides detailed AOs across the eight levels of learning for each learning area which covers the objectives from Year 1 to Year 13. Secondary students are assessed in the AOs for a particular learning area using a range of internal and external assessment and students gain credits once they achieve an AO (NZQA, n.d.-a). A certain number of credits gains them a National Certificate of Educational Achievements (NCEA) certificate which is needed for employers, universities, or polytechnics in NZ and worldwide (ibid). NCEA is conducted by NZ Qualification Authority (NZQA, n.d.-b).

There are many pathways to becoming a teacher in NZ. The undergraduate degree for early childhood education and primary education is of three years and for secondary, four years (Ministry of Education, n.d.-b). If someone has a previous undergraduate degree or higher in another subject, they can qualify to be a teacher by doing a one to two year graduate or post-graduate diploma or a Master of Teaching and Learning (Ministry of Education, n.d.-b). Additionally, prospective teachers can study while being employed as trainee teacher (Ministry of Education, 2019). After studying, teachers are employed and apply to the Teaching Council for registration and practising certificate (Teaching Council of Aotearoa New Zealand, n.d.-a). All teachers need to be registered with the Teaching Council and also need a current practising certificate (Teaching Council of Aotearoa New Zealand, n.d.-b). New teachers have to be inducted, mentored, and meet the standards for at least two years to get a full practising certificate (Teaching Council of Aotearoa New Zealand, n.d.-b). Practising certificate needs to be renewed every three years (Teaching Council of Aotearoa New Zealand, n.d.-b).

NZ schools are governed by school board who must develop and submit planning and reporting documents to the Ministry of Education every year (Ministry of Education, 2016). This report has to specify the targets set by the school and achievement or shortfall against the target. For students from Year 1 to Year 8, twice a year, the school is to provide written reports of progress and achievement to the family (Ministry of Education, n.d.-a). The reports to the family are to be across the range of curriculum areas and include achievement and progress in simple language, including student reflection on their learning (ibid). Besides the mandatory reporting requirements, the Ministry also coordinates a yearly survey about learning called the National Monitoring Study of Student Achievement New Zealand (NMSSA) in association with the New Zealand Centre for Educational Research (NZCER) and the University of Otago (Educational Assessment Research Unit, n.d.). Year 4 and Year 8 students, teachers, and schools are involved in this detailed study. Every learning area is studied once in a four-year cycle (ibid). The national monitoring involves assessments, questionnaires, performance tasks, and interview tasks (ibid).

1.2 Rationale for the study

This study will focus on TE. TE was introduced in the NZC in 1995 as a mandatory learning area and implemented in classrooms from 1999. Compared to other learning areas, it is relatively new in the curriculum. TE evolved from crafts education (de Vries, 2017). Since then, there have been two major revisions in the TE curriculum - once in 2007 to introduce the three strands for teaching TE and the second time in 2017 to introduce digital technologies and computational thinking explicitly as part of TE. The changes of 2017 were to be implemented in classrooms from 2020. The evolution of TE curriculum highlights the flux in this learning area. The relative newness and the flux in this learning area explains the paucity of literature on some aspects of TE implementation in NZ classrooms.

TE is a compulsory subject in the primary schools across New Zealand, but the low volume of research in primary classrooms is detrimental to the growth of the field. Teachers across the world are attracted to teaching integrated Science, Technology, Engineering, and Maths (STEM) and approaches such as Project-Based Learning (PBL), problem-based learning and having Makerspace (provider of 3D printing, CNC machines, laser cutters, and many more) in their schools. The intention is to allow students to express creativity and problem-solve by designing and developing products. In TE, students problem-solve and learn about the technology that surrounds all of us. Introduction of TE in NZ intended to equip students to be informed citizens of the world and use technology knowledgeably and responsibly. There is a significant overlap with the purpose of TE and integrated STEM, PBL, and Makerspace. A well developed curriculum of TE and support for research in all aspects of TE can prove beneficial for many different teaching approaches, teaching methods, and pedagogies.

Formative assessment needs understanding of the student's learning. In TE, students are developing a technological outcome based on a design brief provided to them. Students are encouraged to design and develop a technological outcome different from others in the classroom. As the students' experiences differ significantly, their learning differs. Dialogue is essential as the teacher aims to understand the student's learning and provide steps for the student's progress while the student attempts to articulate their learning and anchor that learning to their current understanding. Formative assessment through dialogue or IFA is essential to the teaching and learning process in TE. However, to begin a dialogue, teachers need a bank of open, higher order questions specific to Technology Education.

The TOCF (Fox-Turnbull, 2018) is a framework of questions for a TE classroom. It was designed to provide early childhood and primary teachers with a tool for improving their technology content knowledge (Fox-Turnbull, 2018). The original framework was designed based on the TE (or equivalent) curricula in NZ, England, and Sweden (Fox-Turnbull, 2018). TOCF was the starting point of this research as it provided questions that the teacher could use to start a dialogue for formative assessment. However, TOCF was modified for use by primary teachers in New Zealand and the modified framework is called the Questioning Framework for Technology - Primary (QFT-P). The main aim of developing and asking teachers to use the QFT-P is to research its use as a formative assessment tool. In line with the Pragmatic outlook of this study, this research is conducted in a classroom with all its complexities. There is no modification made in the environment to enable the use of QFT-P except those that are required for collection of data (for example, audio and video recorders). Teacher's work in the classroom is unending and tough, and any new tool in the classroom needs to be low maintenance, easy to use, low cost, and not increase the teacher's workload substantially.

It was hoped that the analysis of the data would reveal new insights about the formative assessment process in the classroom. Were there prerequisites for the teacher to be able to have formative assessment through dialogue in the classroom? And ultimately, formative assessment through dialogue was to benefit the students but what could be said about student learning once they engage in a formative assessment dialogue?

1.3 My background

My bachelor's degree is in electrical engineering, which I completed from the University of Mumbai, India. Post my bachelor's degree, I worked in electrical engineering companies for nine years. Due to various circumstances, I ended up applying for a program called 'Teach for India', a non-governmental organisation that aimed to supply government and private schools serving low-income communities with qualified professionals. For teaching in these schools, the applicants were offered a five-week residential teacher education followed by two years of monitoring and guidance in-service. As the applicants did not have a formal teaching qualification in India, they were not allowed to teach beyond two years.

I entered into teaching with little knowledge of pedagogy which I quickly learnt in the intensive five-week residential training. However, the next two years of learning on the job were a gruelling experience. While I had to teach with a textbook and teach to test in the classroom in line with expectations from the school in India, I realised that this may not be the correct approach to teaching and learning. Wanting to learn more, I decided to do a Master's degree in education from Finland - a country known for high academic achievement by students.

The two-year Master's degree involved research that inducted me into the world of educational research, sparking an interest in wanting to continue with it. I was interested in studying student talk in the classroom and approaches where students had more autonomy in their education. That led me to Wendy Fox-Turnbull's research in New Zealand and the present doctoral study. The TOCF designed by Wendy Fox-Turnbull was a good starting point for research on teacher-student dialogue in the classroom in TE. This research study in TE combines my engineering knowledge with knowledge in education and pedagogy. Studying dialogue in the classroom for the specific purpose of formative assessment offered an avenue to study student talk in a concrete area of pedagogy.

1.4 Structure of the thesis

This thesis follows the standard structure of literature review followed by methodology followed by the findings, discussion and conclusion in that order. Every chapter begins with an epigraph from John Dewey whose writing on Pragmatism is the paradigm of this research. The epigraphs offer Deweyan perspective on the chapter's contents.

Chapter 2 reviews literature on dialogue, formative assessment, and technology education - the three main areas of this research. The review of formative assessment in technology education is next followed by a discussion of the TOCF. Chapter 2 ends with the research questions that drive this study.

Chapter 3 is the methodology chapter that starts with a explanation of Deweyan Pragmatism, the ontology of this study. The explanation of the paradigm leads to the research design - Design-Based Research (DBR) followed by the methods in this study. Next in this chapter is a discussion of the analytical framework and analysis. This chapter ends with a short discussion of the quality and ethics of the research.

Chapters 4, 5, and 6 are the presentation of findings from this study. Chapter 4 presents evidence mainly from the development process of the framework used in the study. The second findings chapter, Chapter 5, presents results from analysis of data from the teachers - their interviews and audio. The third findings chapter presents evidence from student work.

Chapter 7 is the discussion of the findings. Three sections of this chapter seek to discuss the findings in the wider context of the literature and the research questions. In the first section, the discussion is centred around IFA in TE. The second section focusses on the student learning and the third section discusses the use of QFT-P in the classroom.

The final chapter presents the conclusion for this study highlighting the contributions to the field. The implications of the research, limitations, and future direction for this research, form the bulk of this chapter.

Chapter 2

Literature review

> The principle that development of experience comes about through interaction means that education is essentially a social process (Dewey, 1997, p. 39-41).

No research can begin in isolation – we build on the previous studies, ideas, and thoughts expressed by the many researchers, educators, and teachers who come before us. This section aims to do just that – review what has been known concerning the areas under examination in this study. The three main areas for this review are – dialogue, formative assessment, and Technology Education (TE). The number of research studies and literature in the three areas is vast. The focus of the review is to define the terms used in the study followed by a review of the research that is relevant to the intersection of the three areas. For dialogue, the reviewed literature focuses on benefits of dialogue and the barriers to implementation of dialogue in the classroom. The focus is then narrowed to formative assessment and formative assessment specifically through interactions and dialogue. The next section then reviews and builds connections in the existing literature on the use of dialogue for formative assessment in TE. The final section in this chapter discusses the framework, the Technology Observation and Conversation Framework (TOCF) (Fox-Turnbull, 2018) that was modified and used for formative assessment in TE in this study. The introduction of TOCF is followed by the research questions that drives the methodology that will be discussed in the next chapter.

2.1 Dialogue and Formative Assessment

The aim of this section on dialogue and formative assessment is to establish definitions and some background on the research studies done in these two areas. It begins with broad review of dialogue and then proceeds to formative assessment. A review establishes the imperative for dialogue in the classroom and the various ways dialogue between teacher and students is encouraged and facilitated in the classroom. Barriers to implementation of dialogue is reviewed next followed by formative assessment.

2.1.1 Place of dialogue in classroom talk

Talk between teacher-student and student-student has been the basis for classroom research for many decades. Based on international literature, five main types of talk have been identified in the classroom: rote, recitation, expository instruction, discussion, and dialogue (Alexander, 2001, 2004; D. Barnes & Todd, 1995; Mercer, 2002). The various terms are defined here as per Alexander (2008) as his work has been considered as seminal in this field.

- Rote - "drilling of facts, ideas and routines through constant repetition"
- Recitation - "the accumulation of knowledge and understanding through questions designed to test or stimulate recall of what has previously been encountered, or to cue students to work out answers from clues provided in the question"
- Expository instruction - "imparting information and/or explaining facts, principles or procedures"
- Discussion - "open exchanges between teacher and student, or student and student, with a view to sharing information, exploring ideas or solving problems", and
- Dialogue - "using authentic questioning, discussion and exposition to guide and prompt, minimise risk and error, and expedite the 'uptake' or 'handover' of concepts and principles"

  (Alexander, 2008, p. 34)

One of the earliest instances of studying teacher-student talk was in a United States of America (USA)-based-study in 15 high-school classrooms with 345 students by Bellack et al. (1966). The classroom observation study concluded that teachers structured most of the talk in the classroom and spoke the most. The chief talking pattern in the classroom was recitation and started with teacher asking a question, student responding, and teacher evaluating the response – dubbed Initiation-Response-Feedback (IRF) by Sinclair and Coulthard (1975). A systematic review of research studies published in English by Howe and Abedin (2013) found the dominance of IRF pattern of talk for over three decades (review of studies up to 2011). In IRF patterns, students typically answer in 3-4 words and often answer questions with pre-determined answers (Howe & Abedin, 2013). In a review of research studies from the 1970s, Mercer and Dawes state that educators criticized the IRF pattern of interaction between the teacher and student and recommended teachers minimise the usage of IRF pattern in the classroom (Mercer & Dawes, 2014) as different types of talk enable different types of learning (King, 2002).

Teachers and students talk for multiple reasons besides learning and teaching in the classroom, for example, administrative and discipline purposes. Besides, teacher-student interactions, student-student interactions occur in the classroom and have also been widely researched. However, this study will focus on teacher-student dialogue that involves learning. In Alexander's definition of dialogue, "authentic questions" refers to questions for which there are no pre-determined answers (Nystrand et al., 2003) and 'uptake' refers to the teacher using the students' answers in the follow-up. By this definition, Alexander (2008) aims to extend the traditional understanding of dialogue as talk between two or more people, to a meaningful exchange of ideas between two or more parties that could include some exposition and some discussion. To avoid confusion with the traditional English usage of the word dialogue, some researchers call this "productive dialogue" (for example, Howe et al. (2019)). However, in this study, whenever the term "dialogue" is used, I refer to Alexander's use and definition of the word. As Alexander's definition pertains to the classroom environment, the definition centres the exchange of concepts and principles with teacher integrating ideas from the students who freely offer their thinking about the topic. But why is dialogue necessary in the classroom?

Imperative for dialogue

The traditional "banking" method of education relied on students being passive listeners while the teachers stood in front of the class and passed on the knowledge to the banks of children's minds (Freire, 1996). Educators around the world have long argued for a change in this approach to learning and give students a voice in the classroom, for example, the Bullock Report in the UK in 1975 (as cited in D. Barnes and Todd (1995)). Dewey argued that students using their voice in the classroom is natural and the unnatural approach of traditional schools - making students recite what they have learnt - causes the stifling of development of students' language (Dewey, 1915). He further argued in favour of students using their voice and language to express their learning and listening to others' learning as a means to creating new lines of thought and inquiry (ibid). To offer students a voice is to allow for their empowerment and a space to openly discuss the students' reality (Freire, 1996). Monologue is allied with power and authority and monologic forms including the written word are inherently conservative (Skidmore, 2019). Dialogue offers space for interruptions, spontaneity, and improvisation (ibid).

According to Skidmore, interpreting the works of Russian literary scholar Bakhtin, "It is in dialogue with others that our ideological consciousness is formed" (Skidmore, 2019, p. 33). Dialogue helps students engage actively with the content of what is being taught as well as express their understanding and thus, demonstrate their learning (ibid). Sociocultural theory is based on listening and learning from social interactions. As Vygotsky, a seminal Russian psychologist who pioneered ideas of children's learning and development in context, contended knowledge and meaning are co-constructed and mediated by language, and students' participation is necessary for construction of knowledge (Vygotsky, 1978). Additionally, self, and social reality are part of the talk in the classroom and participation in the talk offers students a chance to establish or change their self and their reality (Wegerif et al., 1999). Duschl (2003) states that students need to have a voice in the classroom so that they can make their learning visible and mediate their learning. Wegerif (2019) argues that dialogue is not only needed for learning but is also an end goal of learning as participation in dialogue can lead learners to being open-minded towards learning. Nystrand et al. (1998) argue on the basis of their research in more than 200 classrooms in USA high schools, that dialogue offers students a space to contextualise the learning to themselves and hence, promote learning. Dialogue, thus, needs to be an essential part of a classroom.

Mercer argued for looking at the purpose and context of the teacher's initial question and not looking at interactions as discrete teaching and learning events (Mercer, 2008a). Using authentic questions prolongs the students' answers and encourages them to participate in the dialogue (Molinari & Mameli, 2010). The IRF sequences could be spiral or cyclical with the teacher continuing to lead the talk but asking for other students' contributions or asking for elaboration or challenges (Edwards & Mercer, 1987). For example, the teacher could ask "Why do you think that?" for elaboration or "Who else agrees/disagrees with the point being made?" for further contributions. Multiple students' replies could lead to a I-R-F-R-F or I-R-F-R-F-R or chains of IRF (Scott & Mortimer, 2005) or I-R-P-R-P or chains of I-R-P-R-P-R-F where "P" stands for prompt by the teacher (Scott et al., 2006).

However, dialogue is not an innate quality that everyone is born knowing how to participate in. For students to participate in classroom dialogue, they need to be able to state their ideas openly, to be able to challenge and expand on ideas, and provide reasoning for arguments (Warwick & Cook, 2019). Teachers need to provide modelling and support for development of students' dialogue so that students have a complex understanding of the subject of the dialogue and become more than rote learners (ibid). There have been multiple approaches presented in literature to increasing dialogue in the classroom that are reviewed next.

Approaches to increasing dialogue in the classroom

Dialogic teaching (Alexander, 2004), dialogic instruction (Nystrand et al., 1998), dialogic inquiry (G. Wells et al., 1999), Philosophy for children (Lipman et al., 1980), collaborative reasoning (Reznitskaya et al., 2001), accountable talk (Michaels et al., 2008), and exploratory talk (Mercer et al., 1999) are some of the approaches to increasing dialogue that have been presented in the literature and are reviewed here. The methods mentioned above are not an exhaustive list but the most recognised in literature. Each of these approaches will be discussed briefly in order to highlight the elements of dialogue in the specific approach and how they are used in the classroom.

Dialogic teaching, dialogic instruction, and dialogic inquiry are approaches based mainly on theoretical ideas of Russian linguist, Mikhail Bakhtin (Skidmore, 2006) and are discussed together as dialogic pedagogy (Skidmore, 2006). Dialogic teaching is a term introduced and elaborated by Alexander (2004), while dialogic instruction is explained in the research study by Nystrand et al. (1998), and dialogic inquiry is explained by G. Wells et al. (1999). The main characteristic of dialogic pedagogy is that students are accepted to be primary contributors of knowledge (Alexander, 2004; Nystrand et al., 1998; Skidmore, 2006). Dialogic pedagogy aims for a balance between authoritative monologue (by the teacher) and dialogue (between teacher-student or student-student) as well as balance between interactive and non-interactive episodes in a lesson (Mercer & Dawes, 2014). The principle inherent in dialogic pedagogy is that authentic questions are posed by teachers and discussed by students offering substantial and significant contributions while the teacher directs the talk in the classroom. Subsequent utterances/questions are built on previous replies and form a chain of coherent and complete enquiry rather than disjointed and incomplete statements (Alexander, 2004). Authentic questions and uptake of student replies form an intelligible conversation that enhances learning. The teachers using dialogic pedagogy must approach it with the mindset that student voice is necessary for learning - an approach that Philosophy for children shares.

Philosophy for children aims to help children learn to think for themselves through dialogue and listening to multiple opinions and viewpoints (Lipman et al., 1980). Philosophy for children is implemented for children from the age of 6-16 years, and can be delivered through reading of novels and texts (Trickey & Topping, 2004). The texts serve as the context for debate and teaching of reasoning skills and the teacher provides an emotionally healthy climate for debate and guides the dialogue through open questions (Trickey & Topping, 2004). The key for the dialogue is to build on each other's ideas and students are encouraged to formulate the questions that they would like to discuss (ibid). In this approach, the key elements to increasing dialogue are the open questions and students building on each other's ideas. The belief that teachers require for this approach is to value differences in opinions and viewpoints in the classroom. This mindset as well as elements for increasing dialogue is also shared by collaborative reasoning approach (R. C. Anderson et al., 1998). The difference between Philosophy for children and collaborative reasoning could be the degree of freedom offered to the student to self-select and direct the dialogue in the classroom with collaborative reasoning offering open participation where students do not need to be nominated to speak (Reznitskaya et al., 2001).

Similar to the approaches discussed above, accountable talk refers to academically productive talk in the classroom that is accountable to the community, to the knowledge, and to accepted standards of reasoning (Michaels et al., 2008). Accountable to community refers to the community of the classroom and accountable to knowledge and standards of reasoning refers to using arguments that follow accepted facts and logic building. In accountable talk, the participants agree to common rules of the classroom for dialogue such as one person talking at a time. Agreement to common rules for dialogue is also a characteristic of exploratory talk (Mercer et al., 1999). Classroom dialogue through accountable talk and exploratory talk is built by listening to others, considering others' ideas and building on ideas logically and drawing reasonable conclusions while ensuring that the dialogue is built on facts (Mercer et al., 1999; Michaels et al., 2008).

The approaches outlined above rely on some common features: students are involved in the construction of knowledge and inquiry process, there is an open exchange of ideas with multiple voices and respectful classroom relations (Haneda, 2016). Across the approaches, the degree of freedom offered to students to self-select to speak and manage the dialogue lies on a spectrum and could be heavily dependent on students' age and their experience in participating in dialogue. Furthermore, in some approaches like dialogic pedagogy, the teachers could be the sole speaker for some of the time but in other approaches like collaborative reasoning and philosophy for children, the teacher only helps in directing the talk, prompting for reasons, and summing up the dialogue. Without a safe environment where students feel secure to offer opinions and thoughts, it is unlikely that students will participate in dialogue. Teachers help in creating a safe environment and additionally, play the role of modelling the different skills required to conduct the dialogue.

Although the necessity for increasing dialogue in the classroom was built on the foundation of socio-cultural theory of learning and honouring students as active participants in the learning process, research has been conducted to offer empirical evidence of the importance of dialogue to the learning in the classroom as well as the barriers to implementation of dialogue-based approaches in the classroom. The next two sections summarise the research on benefits and barriers for all dialogue-based approaches. Research on all types of classroom dialogue including student-student dialogue has been increasing since 1970s (Howe & Mercer, 2017) and has especially grown since 2006 with close to 500 international publications in 2019 (Song et al., 2019).

Benefits of dialogue in the classroom

As dialogue and dialogue-based approaches have been studied since the 1960s, there are many studies across the world that have shown benefits such as students growth in academic topics, conceptual thinking, critical thinking and reasoning, motivation, engagement, self-regulation and social skills, and leadership skills. Various studies across each of these benefits are reviewed. The scope of the review is related to review research published in English language but is not exhaustive.

Teacher-student dialogue in the classroom can lead to gains in understanding in subjects such as maths (Jay et al., 2017; Kyriacou & Issitt, 2007; Mercer, 2008b; Mercer & Littleton, 2007) and science (Howe et al., 2019; Jay et al., 2017; Mercer, 2008b; Mercer & Dawes, 2008; Muhonen et al., 2018). Studies in maths and science reviewed here were pre-dominantly done in the UK in multiple primary classrooms with more than 500 participants. In both these subjects, research done in quasi-experimental methods has found that students, who had an opportunity to explain their reasoning and thinking in depth, have shown academic growth in maths and science. Other studies, pre-dominantly in USA primary classrooms, have found that dialogue increased the academic rigour of reading comprehension (Murphy et al., 2018; Murphy et al., 2009; Wolf et al., 2005, 2006) and listening comprehension (J. Zhang et al., 2013) for students, leading to an overall positive effect in literacy abilities (Jay et al., 2017; Rojas-Drummond et al., 2017). Participating in dialogue was also positively associated with increased grades in language arts in a USA and Finnish study done across grades from primary to high school (Applebee et al., 2003; Muhonen et al., 2018). Collaborative reasoning, an approach to increase dialogue discussed in the previous section, has shown to increase students' usage of academic words in under-served community learners in two USA based studies in primary schools (S. Ma et al., 2017; J. Zhang et al., 2013). In the study by S. Ma et al. (2017), more than 900 students from different economic and racial backgrounds in the fifth grade participating in an integrated unit that taught english, maths, social studies, and science showed growth in academic word usage when they used dialogue. Dialogue is shown to have benefit on students' learning outcomes as well as conceptual learning (Applebee et al., 2003; Howell et al., 2011; Miller et al., 2014; Murphy et al., 2009; Reznitskaya et al., 2009; Wegerif et al., 1999). The research on positive effects on conceptual thinking has been shown in research since 1999 across multiple USA primary schools in multiple subjects.

By participating in dialogue, especially in classrooms where collaborative reasoning has been implemented, systematic reviews of literature has shown that students have shown the ability to write essays with complex and persuasive arguments (Lin et al., 2018; Mercer, 2008b; Reznitskaya et al., 2001) including using more analogies and multilink causal chains (Lin et al., 2018). Additionally, students are able to transfer the learned argumentative skills to other tasks or communicative modes (Reznitskaya et al., 2009). A USA based study with an integrated unit of multiple subjects across 36 primary classrooms showed that students use more relational markers in their arguments (Morris et al., 2018). All of these research studies and literature synthesis suggest that arguments and persuasive writing improved when students used dialogue in the classroom. In a USA based study by X. Zhang et al. (2016), more than 700 primary students were involved in a research that showed that students who were taught to use dialogue amongst each other wrote essays that considered various sides of a dilemma, argument, and weighing the importance of reasons. After being involved in collaborative reasoning, students' social reasoning tended to be more complex and coherent (Lin et al., 2019) and they improved in moral reasoning as well (X. Zhang et al., 2013). Students also showed an increase in critical thinking (Murphy et al., 2018), complex thinking strategies (R. C. Anderson et al., 1998; S. Ma et al., 2017; J. Zhang et al., 2013) and cognitive ability (S. Yan et al., 2018) when they engage in dialogue in the classroom.

Additionally, dialogue has shown to increase engagement in studies done in the USA and China in primary schools (Chinn et al., 2001; Jay et al., 2017; S. Ma et al., 2017; J. Zhang et al., 2013). Students who engage in dialogue for learning showed better self-regulation in a Finnish study (Muhonen et al., 2018), better social skills, and decision making skills in a study based in USA and China (X. Zhang et al., 2016). Students engaging in collaborative reasoning episodes showed less aggression in the classroom, were more socially accepted, improved their communication skills, and worked better in groups and improved the overall classroom experience for the students in a recent quasi-experimental USA based study in primary classroom (Lin et al., 2021). Students gained greater sensitivity to ethical issues and were more likely to consider argument from the opposite perspective (Hennessy et al., 2016; X. Zhang et al., 2013). In one study in the USA, seventh grade maths classroom, participating in classroom dialogue through accountable talk offered English language learners a path to socialisation in the classroom and expanded opportunities for these students in the classroom (Ardasheva et al., 2016).

Students growth in communication, social skills, critical thinking, and reasoning is necessary as part of a repertoire of 21st century skills (Teo, 2019). While the benefits of dialogue in the classroom seem to be myriad, I move on now to consider the barriers to implementing it in the classroom.

Barriers to implementing dialogue-based approaches in the classroom

In studies that discussed benefits for students, there were also reports of barriers that the teachers faced when increasing dialogue in the classroom. It has been shown in the meta synthesis by Howe and Abedin (2013) that teachers lead the talk in the classroom and they talk the most. The meta synthesis reviewed research over 30 years and the monologic practices of the teacher has remain unchanged through that period. The reasons for the enduring practice of teachers dominating classroom talk are manifold. These barriers relate to systemic barriers in the classroom, barriers due to the complexity of dialogue, barriers specific to teacher beliefs and teacher knowledge, and barriers in the professional development process that seeks to bring about change. Moreover, there are certain barriers to students' participation in the dialogue. All these barriers are now presented.

Large class sizes and focus on tests are two major systemic barriers to changing teacher practice (Burbules, 1993). With the focus on tests, teachers are forced to teach the curriculum fully in a limited amount of time (G. Wells & Arauz, 2006). With limited time, teachers find it difficult to listen to students' answers and engage all students in dialogue. Large class sizes compound the problem of limited time. Political pressures through industry, politicians, parents who may have differing ideas about role of a teacher can add further barriers to teachers wanting to adopt dialogic pedagogy in the classroom (Ferniandez-Balboa & Marshall, 1994).

Dialogue is inherently complex, inconsistent, and uncertain and that itself, could be a significant barrier for teachers to implement dialogue in the classroom (Martin & Hand, 2009; Reznitskaya et al., 2009). Increasing dialogue in the classroom is a significant change in practice for the teacher and in two studies carried out in Turkey and Hong Kong with pre-service teachers, it was found that experienced teachers can be reluctant to change their practice that has brought them success over a period of time (Kilinc et al., 2017; Yip, 2001). Teachers in the early-stages of their career may struggle to recognise student thinking in their replies and tend to guide the students to the "correct" answers (G. Wells & Arauz, 2006). One study in four USA primary classrooms concluded that teachers have found it difficult to allow students to decide on turn-taking on their own or choosing their own topics (Chinn et al., 2001).

Implementing dialogue based practices in the classroom requires teachers to change their beliefs in addition to their practice Reznitskaya and Wilkinson (2015) found in USA based study with ten fifth grade teachers. Another USA based study lasting three years with 13 fifth grade teachers found that teachers find it difficult to change their epistemological beliefs and without change in their beliefs, any change in practice is temporary (Wilkinson et al., 2017). In a NZ study with secondary teachers, an additional barrier that has been identified has been teacher expertise and teacher content knowledge (Davies et al., 2017). Teachers need to have subject expertise to be able to co-ordinate dialogue in the classroom. Teacher expertise in allowing for different perspectives to emerge and establishing an emotionally safe environment in the classroom could also be a barrier to encouraging dialogue (Ferniandez-Balboa & Marshall, 1994).

To change the teacher practice, professional development is sometimes provided for in-service teachers. Learning in professional development contexts is complex and may be mediated by various cognitive, affective, emotional, situational, and organisational factors (D. Clarke & Hollingsworth, 2002). Moreover, scalability has always been an issue for any idea in educational practice (Howe & Mercer, 2017). Recently, professional development has depended on video analysis which is time-consuming and labour intensive (Davies et al., 2017). A longitudinal research in the USA with one primary science teacher found that time for professional development needs to be extended (Martin & Hand, 2009). A systematic review concurred with the finding and concluded that even though professional development is often offered as a one-off workshop, significant change in practice requires ongoing professional support and time (Schneider & Plasman, 2011).

There are barriers to participating in dialogue for students as well. If classroom practice is changed suddenly, students can be resistant to change (Bossér & Lindahl, 2019; Zeidler, 2003). If the established methods in the classroom are suddenly changed, students can find it difficult to accept and work with new practices. Students could have a legitimate fear of voicing their opinions if they have been discouraged from doing so previously. If the students were previously exposed to the banking method of teaching, they may learn to rely on teachers as the owner of knowledge and may see themselves as ignorant and passive (Ferniandez-Balboa & Marshall, 1994). Psychological barriers such as fear of speaking publicly, being misunderstood or being vulnerable can hamper students from speaking up (ibid). Howe and Abedin (2013) in their meta synthesis of articles on dialogue, mentioned that gender was a significant barrier in students participating in dialogue in the classroom. Girls may not get as much an opportunity to talk in the classroom as boys. In various studies that were analysed in the meta synthesis, it was noted that teachers call on boys more often than girls to respond and provide more feedback, both positive and negative, to boys (Howe & Abedin, 2013). Students from different socio-economic backgrounds could also face difficulties in participating in the dialogue (Michaels et al., 2008). Language could be a significant barrier that could hamper students' participation in classroom. Evidence from studying minority groups is quite mixed and seems to depend on the mix of the minority group that was studied (Howe & Abedin, 2013).

Literature review on dialogue indicates that increasing dialogue in the classroom has several compelling advantages but also has significant barriers. However, a good starting point for implementation of dialogue is through a medium that is used by teachers everyday - questions.

2.1.2 Questions

Gall (1970), in his research calculated that teachers ask questions 300-400 times in the classroom in a single day. Most interactions between teachers and students in the classroom begins with a teacher asking questions. Aside from questions related to administration or behaviour management, teachers ask questions either to promote thinking or to plan their next steps in the classroom (Wiliam, 2011). Questions typically set-off conversation in the classroom. The initiation request in the ubiquitous IRF pattern is typically a closed question (Sinclair & Coulthard, 1975). A closed question refers to a question with a pre-determined answer that is typically answered in few words. In contrast, an open question does not have a single answer and may need more than a few words to answer. A balance in the mix of open and closed questions is recommended in literature to keep the dialogue between teacher and students dialogic and purposeful to the learning in the classroom (Furtak et al., 2016).

Teacher's decisions on the kind of questions to ask determines the extent of further interaction in the classroom (Wolf et al., 2006). If the teacher asks more thought-provoking, open, and authentic questions, it could be the key to high-quality classroom dialogue (King, 2002; Wolf et al., 2006). Students tend to respond to open and authentic questions with detailed answers that offer reasoning and justifications (Chinn et al., 2000). If these authentic questions resonate with the students' personal experiences and the teacher offers space for them to link these experiences to their learning in the classroom, students are more likely to learn the new knowledge (Muhonen et al., 2016). The IRF structure can begin with open question (G. Wells et al., 1999), and the teacher can continue the interaction pattern by encouraging students to elaborate on their thoughts, reason and justify their thinking, challenge each other thus making students' learning explicit (Mercer & Littleton, 2007). Ruiz-Primo (2011) suggests use of open-ended questions that taps into diverse types of knowledge for the purpose of IFA. Questions can tap into multiple types of knowledge – declarative, procedural, schematic, and strategic knowledge (Li, 2002; Li et al., 2006). These four knowledge types offer space for students to express what, how, why of the learning in addition to where else they can apply it. Declarative questions can be closed questions as they elicit pre-specified declarative knowledge.

The classification of high-cognitive and low-cognitive questions is based on Bloom's taxonomy (Bloom et al., 1956). High cognitive questions are generally questions that require the students to use the taught information and apply reasoning to create an answer or explain their thinking – occupying the apply, analyse, and create part of the Bloom's taxonomy (Bloom et al., 1956). Examples of high-cognitive question starters could be *What if....?, In your opinion, what could...?, Why...?, How could you change...?, What are the pros and cons of ...?, What can you infer....?, Why do you think...?*. High-cognitive questions are needed to increase dialogue in the classroom. A meta-analysis by Redfield and Rousseau (1981) concluded that student achievement improved when teachers asked high cognitive questions. But studies summarised by Myhill (2006) found that teachers rarely ask high-cognitive questions.

High-cognitive, open questions for a specific subject and context may be difficult to formulate spontaneously (Wiliam, 2011). Besides knowledge of the subject, high-cognitive questions may also need knowledge of the students and common alternate conceptions of the topic (Leahy et al., 2005; Wiliam, 2009). It has been suggested that good questions need to be pre-planned to provoke thought and sustain dialogue (H. L. Andrade et al., 2019; Shavelson, 2006; Wiliam, 2011). It may be difficult for teachers working in isolation to come up with good questions on their own. Hence, good high-cognitive questions need to be carefully thought out and shared amongst teachers (Wiliam, 2011). Teachers can build a bank of good questions to ask students. Previous research, thus, reinforces the need for planned high-cognitive questions in the classroom for assisting teachers to sustain dialogue. One of the drivers for selection of a framework for this study, is based around this need for teachers to have an access to a bank of high-cognitive questions.

While dialogue can serve multiple purpose in the classroom, this study focusses on dialogue for formative assessment. The next section reviews literature regarding formative assessment.

2.1.3 Formative assessment

Formative assessment is especially helpful for students and is linked to substantial learning gains (Black & Wiliam, 1998). Evidence elicited from a formative assessment process improves the instruction in comparison to if the formative assessment was never conducted (Black & Wiliam, 2009). Formative assessment has been defined in various ways by various educators and researchers but there is no agreed upon definition (H. L. Andrade et al., 2019). In the Handbook of Formative Assessment in the disciplines (H. L. Andrade et al., 2019), the editors propose a “next-generation” definition of formative assessment that accounts for all the research and updated understanding of formative assessment. According to this definition, it is to be recognised that,

> As part of a planned assessment system, formative assessment supports teachers' and students' inferences about strengths, weaknesses, and opportunities for improvements in learning. It is a source of information that educators can use in instructional planning and students can use in deepening their understandings, improving their achievement, taking responsibility for, and self-regulating, their learning. Formative assessment includes both general principles, and discipline-specific elements that comprise the formal and informal materials, collaborative processes, ways of knowing, and habits of mind particular to a content domain (Cizek et al., 2019, p. 14).

As per this definition, the purpose of formative assessment is to infer about students' strengths, weaknesses, opportunities, and areas of improvement in the learning process. An inference is made for the purpose of guiding students on their learning and can be used by teachers to modify their lesson plans. This updated definition factors in students' self-regulated learning, metacognition, and both teachers' and students' collaborative role in formative assessment while also adding that formative assessment is part of a planned assessment system. However, as Wiliam (2019) argues, a highly prescriptive definition can render any practice that does not completely fit as not formative assessment and that can be counter-productive. Hence, for this study, a simpler definition of formative assessment was sought that can include the essential elements of looking at students' learning and using the information about the students' learning to either change the teaching or guiding the students to the next step in their learning. One such definition is given by Cowie & Bell where formative assessment is defined as “*the process used by teachers and students to recognise and respond to students' learning in order to enhance that learning, during the learning*” (Cowie & Bell, 1999, p. 101). This is the definition adopted in this study.

There are two main aspects to formative assessment as defined: the elicitation of the students' learning and the teacher's response or feedback (H. L. Andrade et al., 2019). The recognition of student learning is critical aspect of formative assessment - however, it is not considered as a separate observable step - except in its consequence. The teacher's feedback is one of the most essential elements of formative assessment (Black, 2009a). In a widely cited article, Hattie and Timperley (2007) on basis of multiple synthesis of meta-analyses, state that feedback can be thought of as the information provided by the teachers to the students regarding their learning. This information can be in the form of approval, clarification of ideas, alternative ideas or strategies, encouragement, or corrective action (Hattie & Timperley, 2007).

Formative assessment lies in a continuum from formal to informal assessment (Shavelson et al., 2008). Formal formative assessment is commonly understood as planned and prepared by the teacher prior to the lesson to ensure that the lesson objectives are being understood by the students while informal formative assessment is enacted spontaneously in the classroom (Cowie & Bell, 1999). This study focusses on the informal end of the continuum of formative assessment on a type of informal assessment called Interactive Formative Assessment (IFA).

2.1.4 Interactive formative assessment

Some amount of assessment is always occurring in the classroom and is inherent to any human interaction (Jordan & Putz, 2004); for example, a teacher repeating instructions based on their interpretation of students showing signs of not following along. In literature, assessment that is done on-the-fly is called interactive formative assessment (Cowie & Bell, 1999), or informal formative assessment (Ruiz-Primo & Furtak, 2006), or inherent/discursive assessment (Jordan & Putz, 2004), or assessment on-the-fly (Shavelson et al., 2008). Informal formative assessment may or may not be recorded and can be oral, written down in notebooks, drawings/ sketches, observations, and non-verbal (Ruiz-Primo, 2011). Ruiz-Primo uses the term assessment conversation, first used by Duschl and Gitomer (1997) to refer to formative assessment carried out through dialogue. Interactive formative assessment or IFA is used in this study to focus on oral informal formative assessment.

IFA is on the border of teaching and assessment and is an integral part of the process (Alexander, 2004; B. Bell & Cowie, 2001). Through talking to the students, teachers can formatively assess in real time and listen for any misunderstandings and gaps in student learning and provide immediate feedback (B. Bell & Cowie, 2001; Black et al., 2003; S. Clarke, 2008). IFA is transient (B. Bell & Cowie, 2001) - normally not captured in the classroom in any document or worksheet or teacher notes. The transient nature of IFA implies that the information received in the IFA must be utilised immediately before it is forgotten.

IFA has the advantage of flexibility and discreetness in comparison to formal assessment (summative or formative). Unlike IFA, formal assessment could result in teachers teaching to the test as well as stress to the participants (Jordan & Putz, 2004). In addition, IFA is student referenced and criterion referenced (B. Bell & Cowie, 2001) –

the teacher feedback in the IFA depends on the student that they are talking to and the established learning goals for that lesson. Thus, IFA is flexible and teachers can use IFA based on their judgement of the students' needs.

Few studies have specifically investigated IFA. Two key articles were identified - B. Bell and Cowie (2001) and Ruiz-Primo and Furtak (2007) that proposed models for IFA and are reviewed in the next section.

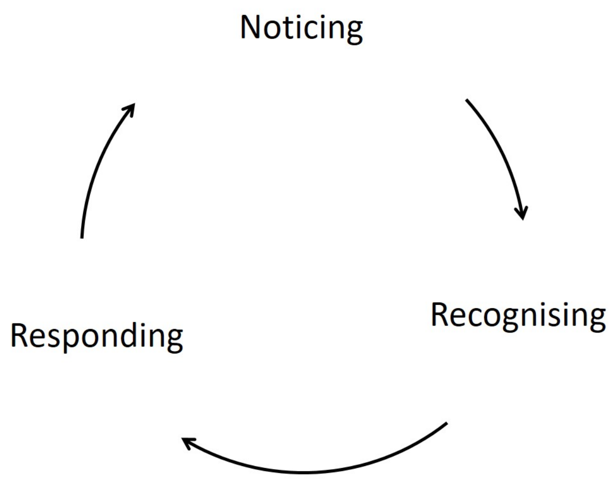
2.1.5 Models of Interactive Formative Assessment

According to B. Bell and Cowie (2001), IFA involves teachers noticing, recognising and responding to student thinking. This model is shown in Figure 2.1. Many things happen simultaneously in the classroom. For this reason, one of the key features of IFA is the teacher's ability to notice the most relevant data in the classroom as the first step (B. Bell & Cowie, 2001; Sherin & van Es, 2005), especially due to the transient nature of interactions. Teachers' noticing can lead to further questioning to get a clearer picture of the students' learning (B. Bell & Cowie, 2001). Following the noticing, the teacher must recognise what the student is exhibiting through their actions or replies. Once the teacher recognises where the student is in their learning, they can offer response to the student either by offering feedback, further action steps, or challenging their thinking. B. Bell and Cowie (2001) proposed that the response is based on care, the student, and the subject that was being taught .

In the second model IFA follows the Elicitation-Student response-Use (ESU) pattern of conversation. Elicit (E) refers to strategies by the teacher that makes students' learning explicit; the student then responds (S) to the elicitation moves; as the student responds, the teacher then recognizes the student learning, and uses the information (U) to help the students move towards the learning goals (Ruiz-Primo & Furtak, 2007). This model is represented in Figure 2.2. This pattern could involve multiple cycles of incomplete interactions before the dialogue was complete (Ruiz-Primo & Furtak, 2007). Earlier the model was referred as ESRU model where the 'R' referred to the teacher recognising the student learning. However, as the teacher recognising the student response and using the information co-occur, in later literature, both these steps are shown in a single step (Furtak et al., 2017).

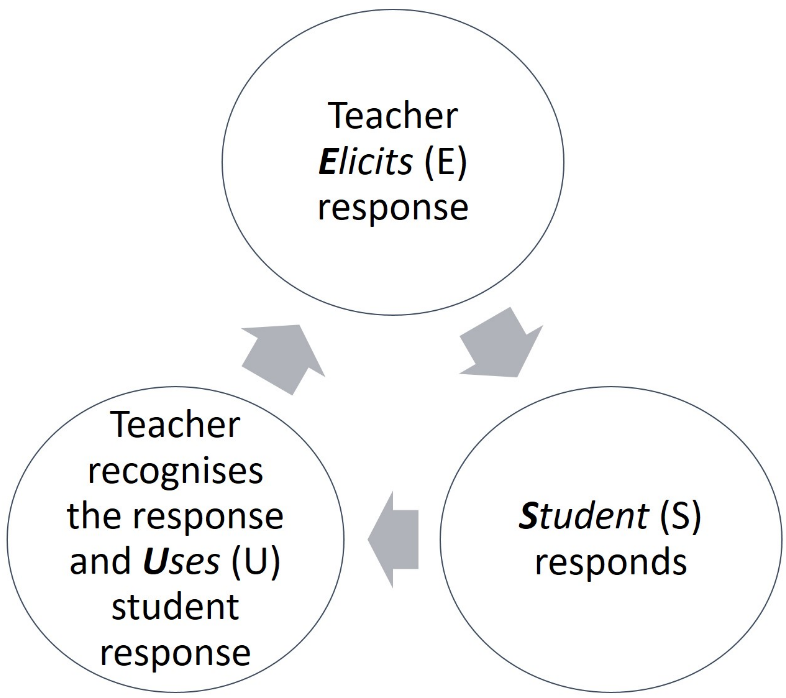
Ruiz-Primo and Furtak (2007) emphasise the importance of the last step – Using the student response - in the ESU cycle. The teacher can use the information from the student response in any number of ways – either towards a detailed evaluation of the responses, to formulate another question, to redirect the student thinking, to provide

Figure 2.1
Interactive formative assessment process by Bell & Cowie



Recreated from Formative Assessment and Science Education (p. 86), by B. Bell & B. Cowie, 2001, New York, USA: Kluwer Academic. Copyright 2002 by Springer. Used with permission

Figure 2.2
ESU model of Interactive Formative Assessment



Created from Exploring teachers' informal formative assessment practices ad students' understanding in the context of scientific inquiry by Ruiz-Primo & Furtak in Journal of Research in Science Teaching 44(1),57-84.

students with information on specific actions they may take to reach learning goals, to encourage better communication methods, to allow students to explore ideas further, to support deeper thinking, to reinforce learning, or to increase/decrease level of difficulty of the task (Ruiz-Primo & Furtak, 2007). The teacher can encourage students to think deeply by asking them to make connections, compare and contrast ideas, or explore relevant topics. The "using" is the teacher offering feedback. There are some conditions to be met for an effective IFA (Ruiz-Primo, 2011). The conditions are that IFA should be learning goal guided, dialogic and interactive, scaffolding tools, supportive tools of social participation and social cognition, and enculturation tools (Ruiz-Primo, 2011).

The two models are quite similar and fit the definition for formative assessment used in this study. The models dive deeply into the interaction specifically for formative assessment purposes. The models focus on teachers' recognition of the learning and their immediate (relative) response to that learning to enhance the learning. As mentioned in the section on dialogue, the key features of dialogue are the teacher beginning with an open question and the further interactions building on the previous responses. Thus, the IFA between the teacher and student is a dialogue.

Some studies have shown that IFA helps to improve student achievement. Sezen-Barrie and Kelly (2017) studied IFA of four middle school teachers in the USA. Teachers reflected on their IFA practice and while they initially did not recognise the importance of IFA, after observing videos of their lessons in the classroom and Professional Development (PD) sessions, teachers in that study realised how IFA helped them guide students in their learning. The researchers mentioned that "*the teachers came to see IFA as a process of ongoing assessment and readjustment (metaphorically, a video of everyday life), rather than as a measure of achievement at a given time (a still shot photograph)*" (Sezen-Barrie & Kelly, 2017, p. 208). The students in that study scored higher in external, standardised tests because of IFA in the classroom. Another study (Correia & Harrison, 2020) concluded that the way teachers use questioning and IFA promotes students' autonomy and self-regulation.This research was part of a larger study with science teachers across four countries – Finland, France, Cyprus, and England (C. Harrison et al., 2018). The vignettes from the classrooms suggest that IFA practice is complex, challenging and demanding for teachers and required considerable time in professional development. Another study conducted in the USA in mathematics classrooms of grades 1-5 (Park et al., 2020) found that teachers asked closed follow-up questions and students were passive in the classroom conversations that were observed. They concluded that pre-service teacher education programs should help develop IFA practices. A study on pre-service teachers in Hong Kong (Chan & Yau, 2021) among 15 pre-service teachers found that pre-service teachers found it difficult to apply relevant skills or knowledge to identify student thinking and propose productive responses in real time to move student thinking forward, in a complex, fast-paced classroom environment. The reviewed studies offer a glimpse of IFA as a complex practice that is further complicated in a classroom environment.

Ruiz-Primo and Furtak (2006, 2007) conducted a study with three inquiry-based science teachers teaching middle school. According to this study, ESU cycle can occur in multiple iterations - complete or incomplete. The researchers studied the relation between completed and non-completed ESU iterations and cycles and student achievement. They found that the presence of complete ESU cycles in the classroom was found to be correlated to higher student achievement (Ruiz-Primo & Furtak, 2007). According to the study, the teacher using the information from the students is critical to student achievement (Ruiz-Primo & Furtak, 2007) and the incomplete cycles are often the teacher not using the students' response to guide their learning forward. Rached and Grangeat (2021) design-based study focused on lower secondary teachers in STEM in France. They concluded that effective IFA practices occurred when there is frequent interaction with students and teachers asked complex, high-cognitive questions with view to gauge students' progress in understanding and not looking for a "correct answer" or a pre-determined answer. Further, effective IFA involved using the information collected through the IFA process to guide students towards their learning goals. The study also showed that the teachers used complete ESU cycles one-third of the time and teachers that engaged in complete cycles tend to ask cognitively more demanding questions. In Finland, another research project focused on IFA in a physics classroom (Nieminen et al., 2021). In this study, IFA was coded for both form and function. While the coding related to the form of IFA was based on the ESU model, the functions of IFA were recognised as – checking or examining thinking, correcting or developing thinking, redirecting thinking, and reviewing thinking. Nieminen et al. (2021) concluded that knowing the functions of the IFA can determine how teacher-centred or student-centred the assessment was. The functions of IFA are similar to the list of ways to use the information researched by Ruiz-Primo and Furtak (2007).

On reviewing the different research studies in IFA that are available from different parts of the world, it can be seen teachers practicing IFA can expect to see some positive benefits. However, due to the complexity of IFA, it appears to be difficult to implement and few research studies have dealt in-depth with analysing dialogue in IFA. The recent studies in IFA have focused on ESU model of IFA for analysis and there is emerging evidence that complete ESU cycles are likely to relate to better student achievement, at least, in science. Teachers who offered feedback to students in the using part of the ESU cycle achieved better results in relation to student achievement.

2.1.6 Section Summary

This section started with the definition and literature review on dialogue and concluded with IFA and literature review on IFA. There are multiple approaches to increasing dialogue in the classroom. The two key elements of dialogue that seem to be common in the multiple approaches to increasing dialogue in the classroom are authentic questions and uptake of student replies in the follow-up. Research on dialogue shows that when students participated in dialogue for learning in the classroom, they grew academically in multiple subjects and showed growth in conceptual thinking. Besides academic growth, literature reviewed surmised that students showed growth in motivation, engagement, self-regulation, and social skills when they participated in dialogue in the classroom. Despite the established positive benefits of dialogue, there are many barriers to increase dialogue in the classroom: systemic barriers (such as requirements of standardised assessment), class size, teacher's beliefs about importance of student voice, limitations with professional development programmes intent on promoting dialogue, and barriers to students' participation in dialogue.

IFA is the dialogue between teacher and students carried out for the purpose of formative assessment. IFA includes the advantages of dialogue as well as of formative assessment – both have been well-established in literature and through research studies. Any advantages or barriers of implementing dialogue in the classroom is equally applicable to using dialogue for formative assessment. Literature review on IFA, despite being sparse, enumerates the same challenges that implementing dialogue in the classroom brings – lack of time, teacher beliefs on importance of student voice, classroom structure, teacher's content knowledge, and social norms of the classroom. The research studies in IFA are still evolving with researchers coding IFA for the purpose of identifying elements that can be useful to develop and guide student thinking and improve learning. However, many of the studies reviewed here were conducted in the context of science and it is not known what IFA in other disciplines might look like.

Since the context of my study is TE, the next section will focus on TE before discussing the research on IFA in TE.

2.2 Technology education

This section discusses the literature relating to the context of the study – Technology Education (TE). TE around the world has had a turbulent history as it is a relatively new subject introduced in the 20th century despite technology being around as long as humans have existed (J. P. Williams, 2012). In this study, technology is defined in line with NZC as "*Technology is intervention by design: the use of practical and intellectual resources to develop products and systems (technological outcomes) that expand human possibilities by addressing needs and realising opportunities*" (Ministry of Education, 2018a, p. 32). The key element is the aspect of intervention that is specifically planned based on a specific need or to expand possibilities. Technology would not exist without a consumer – someone who needs the technology to solve a problem or meet a need or go beyond what the current situation allows them to.

This section starts with a brief review of TE mainly regarding its evolution. TE in NZ is discussed next as it is the prime focus for this study. I review the way the curriculum defines TE and how it is implemented in schools. The curriculum for TE in NZ is reviewed briefly. The various documents that are of importance in planning and executing TE lessons in primary classroom follows the review of the technology curriculum. TE can be taught using multiple approaches and some approaches are reviewed.

2.2.1 Technology education around the world

Technology education is called by many names in the countries where it is implemented in the curriculum. The most prominent countries to include TE at school level are NZ, Australia, UK, Sweden, South Africa, Taiwan, Germany, Netherlands, Israel, parts of USA and Canada (de Vries, 2017). While the New Zealand Curriculum (NZC) refers to the learning area as TE, England refers to it as "Design and Technology", other countries refer to the subject in various combinations of design, technology, craft, or engineering. Except for rare exceptions, technology education around the world evolved from the aim to develop crafts skills (de Vries, 2017; Doyle et al., 2019) and involved learning activities and skills where every student made the same product. Today, there are many approaches to TE – some countries have it as compulsory part of the curriculum (for example, NZ and UK), some countries integrate it with other subjects (science in Israel, IT in Australia), some countries focus on content, and some on process (J. P. Williams, 2012). Every country implements TE in the way that aligns with their priorities and philosophy (ibid). However, there is general confusion between using technology (like ICT) for education often called as educational technology and TE (Brown & Brown, 2010).

While initially TE suffered in being established from its association with craft, vocational education, and being "applied science", the recent movements of STEM education, teaching the 21st century skills have helped TE gain popularity (de Vries, 2017). However, TE still struggles for recognition and formal inclusion in the official curriculum in various countries and has been saved multiple times in different countries by the imploring of international TE educators writing to governments about the importance of TE (de Vries, 2017). TE is not well understood by those outside compulsory schooling (D. Bell et al., 2017). One of the major reasons for this struggle is the lack of understanding of governments and society around the philosophy of TE and belief that it does not have its own discreet set of knowledge or skills (D. Bell et al., 2017).

The philosophy of TE envisages teaching of TE in four main categories: technology as artefacts, as knowledge, as activities, and an aspect of humanity (Mitcham, 1994). All four aspects are interlinked and not needed to be taught separately (Jones et al., 2013). Artefacts refer to the products of technology and have two aspects – physical and functional (Jones et al., 2013). (In this study artefacts are referred to as technological outcomes for specificity). Teaching technology as artefacts is the most commonly understood way of teaching technology. Knowledge in technology cannot always be transferred through reading books and may need practical lessons – knowledge in technology may or may not be propositional (Jones et al., 2013). Teaching technology as knowledge implies having to teach the associated knowledge and skills in making a technological outcome. In craft education, the teaching of skills and knowledge was considered an important aspect of teaching crafts. Technology as activities has its relevance in design and technology (Jones et al., 2013). Designing a technological outcome is an iterative process and is informed at all stages by stakeholder feedback and resource consideration. Approaching technology education as a design activity is an important way that TE can be distinguished from craft education. Technology as an aspect of humanity relates to how humans and societies are interlinked and are influenced by each other (Jones et al., 2013). It involves consideration of the impact and ethics of using technology. The philosophy of technology clarifies what TE should be taught as and the many aspects that need to be covered. The change in focus from craft to TE has caused a corresponding evolution in the style of teaching – a master-apprentice style to "authentic learning" style (de Vries & Mottier, 2006).

TE research before the year 2000 focused mainly on the curriculum content of TE (J. P. Williams, 2017). Between 2000-2008, a systematic literature review by Middleton, showed that research focus had shifted to teaching and learning of TE (ibid). Jones and de Vries (2009) noted that despite the increase in research on teaching and learning in TE, more research needed to be carried out involving the teachers as partners in the research process. J. M. Ritz and Martin (2013) carried out research among TE educators and researchers worldwide to find out the most needed research areas in TE through the Delphi technique. Their study concluded that research was needed in the areas of benefits to students studying TE and how students learn TE (J. M. Ritz & Martin, 2013). Their study investigated the issues that affect the teaching of TE and the results showed that there was a lack of knowledge about the epistemic beliefs of teachers, lack of knowledge about how design activities should be taught, and lack of knowledge about the Pedagogical Content Knowledge (PCK) of teachers (J. M. Ritz & Martin, 2013). A meta-synthesis by Williams indicated that curriculum and design remain main focus of research for the years 2006-2015 and research on STEM has increased in the same time-period (J. P. Williams, 2017). The research on STEM could be a threat or an advantage to the position of TE in curricula worldwide and the definition of technology within STEM may need redefinition (ibid). Williams discussed that there is more research on how students learn technology as well as more research in primary and early childhood. NZ has well-supported TE since its introduction in 1995 in the NZC. The next section discusses TE in NZ.

2.2.2 Technology education in New Zealand

TE requires students to know the practical and intellectual knowledge needed for designing and developing products or systems to meet identified needs or address opportunities. As the NZC document explains, there is no end point of technological development. Products and systems are influenced by the cultural, environmental, and ethical factors as well as economic and political climate (Ministry of Education, 2018a). As these factors change, so will people's technological needs.

In NZ, students learn technology broadly to develop technological literacy for two purposes – that they can understand technology that surrounds them and to gain access to technology related careers (Ministry of Education, 2018a). The study involves both – developing practical skills of working with different materials and learning the historical and contemporary aspects of technology. The areas offered by schools are extensive and include hard materials (like wood, metal, and plastics), soft materials (like paper, textiles), electronics, food, visual communication, and computer software and systems.

Technology education in NZ was introduced in the NZC in 1995 (Compton, 2011) and is mandatory for students in Years 1-10 (ages 5-15). When first introduced, TE was taught in one-off sessions along with science and social studies (ibid). In the beginning, the key issues of implementing TE were the lack of knowledge around assessment, progression of learning in technology, and compatibility with NCEA (ibid). The TE curriculum underwent two revisions – in 2007 and in 2017 (Compton, 2011; O'Sullivan, 2011). In 2007, the learning area was structured in three strands and the Indicators of Progression (IoP) were released (Compton, 2011; Milne, 2018). There was more clarity on how TE was to be assessed in secondary schools. In 2017, the curriculum underwent further change with introduction of computational thinking and digital technologies explicitly as part of TE curriculum (Milne, 2018). The curriculum document implemented in 2020 is now discussed.

Technology curriculum in NZ

Technology in NZ is taught through three strands: Nature of technology, Technological practice, and Technological knowledge (Ministry of Education, 2018b). These three strands relate to the four main categories of technology as explained in the philosophy of technology mentioned earlier - Technology as artefacts, as knowledge, as activities, and as aspect of humanity. Nature of technology is related to the aspect of humanity and explores the influence of technology and human activities on each other. Technological practice strand relates to technology as activities and as artefacts and Technological knowledge relates to technology as knowledge (Jones et al., 2013). By integrating the four categories of technology into three strands, students are able to reflect on the technological outcome they are going to develop, the knowledge needed to develop the outcome, the learning from making the outcome, the design process they are using to develop the outcome, and the values related to the outcome (Jones et al., 2013). The three strands are further divided into components explained in Table 2.1. The components for Nature of Technology (NT) are Characteristics of Technology (CT) and Characteristics of Technological Outcomes (CTO). Components for Technological Practice (TP) are Brief development (BD), Planning for Practice (PP), and Outcome Development and Evaluation (ODE). The components for Technological Knowledge (TK) are Technological Modelling (TM), Technological products (Tp), and Technological systems (TS).

Teachers teach through five technological areas – computational thinking, digital outcomes, material outcomes (textile, resistant materials like wood, metal, etc.), processed outcomes (food, biotechnology), and design and visual communication. AO are specified for the components at every level except for computational thinking and digital outcomes which have progress outcomes instead (Ministry of Education, 2018b). As per the curriculum document, by working in different contexts, students begin to build links between technological areas and encouraged by teachers, students build on knowledge from other learning areas and key competencies (Ministry of Education, 2018b). The Ministry additionally published IoP to guide teachers on understanding of students' progression in technology.

Indicators of progression

IoP "*unpack the achievement objectives at each level of the curriculum, describing the knowledge, skills, and understandings that students should be demonstrating when achieving at the specified level*" according to the Ministry of Education run website

Table 2.1
Strands and components in Technology Education in NZC

Strand	Components	Description
Nature of technology (NT)	Characteristics of technology (CT)	Studying about technology in general and how it is influenced by society and its influence on society.
	Characteristics of technological outcomes (CTO)	Studying how technological outcomes are fit for purpose and interpreting the social and historical context of its development and use.
Technological practice (TP)	Brief development (BD)	Developing a brief involves knowing and understanding the need for the technological outcome to be developed and the list of attributes for the outcome to be acceptable.
	Planning for practice (PP)	Planning the practice is a dynamic process that enables the outcome to be developed.
	Outcome development and evaluation (ODE)	Outcome development starts with the generation of design ideas and ends with the evaluation of the outcome prior to its use in the actual context.
Technological knowledge (TK)	Technological modelling (TM)	Technological modelling is the testing of design ideas through functional modelling and prototyping.
	Technological products (Tp)	Technological products involves studying the composition of the material and related effects on the performance of the final product.
	Technological systems (TS)	Technological systems are sets of interconnected components that transform, store, transport, or control materials, energy, and/or information for particular purposes.

Note: Descriptions are adapted from Technology Online website owned by Ministry of Education, NZ (http://technology.tki.org.nz/Technology-in-the-NZC retrieved on 20 Jan 2020)

Technology Online (Te Kete Ipurangi, n.d.-b). IoP are written for teachers as a guide to plan, teach and assess their technology units. The IoP is available in a tabular format split into three strands and eight levels of AO. The column headings are the components (Characteristics of Technology (CT), Characteristics of Technological Outcome (CTO), Outcome Development and Evaluation (ODE), etc) and three rows are: the objectives for that level, teacher guidance notes, and indicators that students demonstrate on learning the AO. The IoP are available from Level 1 to Level 8.

Example of Level 1 AO for Brief Development (BD). The first row is the AO for that level. In this case, the AO is "*Describe the outcome they are developing and identify the attributes it should have, taking account of the need or opportunity and the resources available*". The AO is quite generic as it has to apply for different technological areas and multiple contexts. The AO may need further explanation for teachers and other TE educators. The teacher guidance notes provides guidance for teachers on what they can provide to students for that specific AO. For Level 1, BD, the teacher guidance notes are as below.

> To support students to undertake brief development at level one teachers could:
>
> - provide the need or opportunity and develop the conceptual statement in negotiation with the students
> - provide a range of attributes for discussion
> - guide students to identify the attributes an appropriate outcome should have

The teacher guidance notes in the example suggest to teachers that in order for the students to fulfil the AO, they may need to provide guidance about attributes of the technological outcome after they discuss the need or opportunity with the students. The last row of the IoP describes the indicators that students need to exhibit to be assessed as fulfilling the AO. For example, in case of Level 1, BD, the student indicators are:

> Students can:
>
> - communicate the outcome to be produced
> - identify attributes for an outcome

The IoP offer a steady progression of technological skills and knowledge. For example, for BD, one of the student indicators for Level 1 is "*communicate the outcome to be produced*". The same indicator for Level 2 is "*explain the outcome to be produced*", and the Level 3 indicator is "*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*" (Te Kete Ipurangi, n.d.-b). In this study, for primary students up to age 10, up to Level 3 is relevant (Milne, 2018; Ministry of Education, 2018a).

Besides the curriculum documents, the Ministry supports the Technology Online website that offers resources for teachers such as exemplars of TE lessons, videos, webinar recordings, and research articles in addition to the curriculum documents. The Ministry also co-ordinates NMSSA - a survey and testing in technology every four years (Ministry of Education and NZCER, 2016).

Monitoring of technology education in NZ

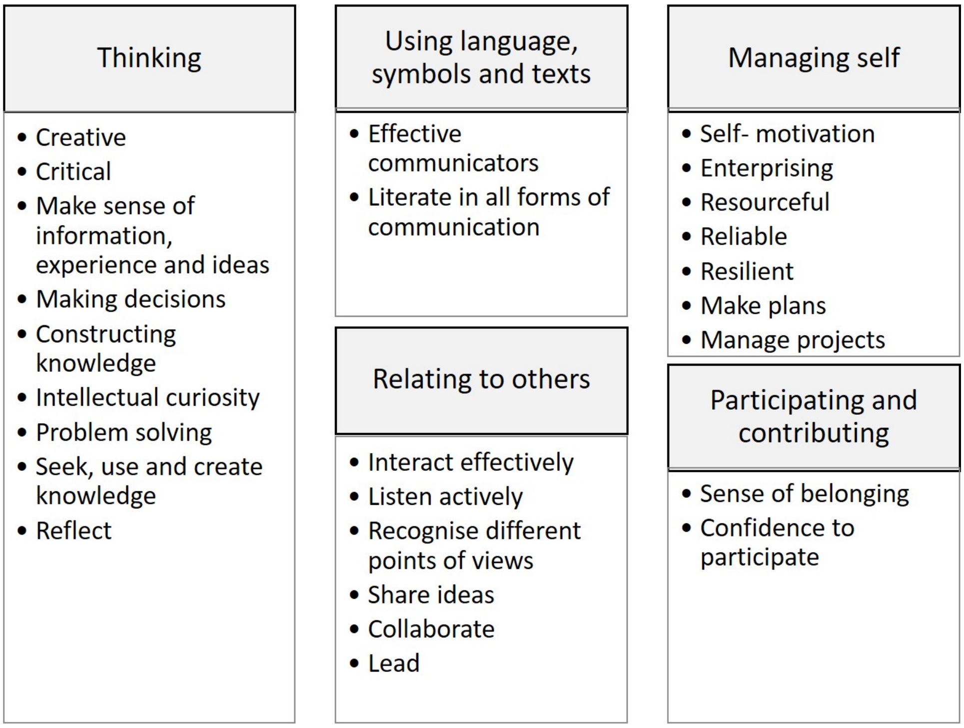
To assess and understand student achievement in schools, the Ministry commissioned a study consisting of survey and a test across all learning years under the study named NMSSA. For technology, this survey is conducted every four years. The latest survey for NMSSA was conducted in TE in 2016 where Year 4 and Year 8 in schools across the country participated. In total, 200 schools and around 2300 students, 501 teachers, 182 principals participated (Ministry of Education and NZCER, 2016). The students take a TE test that covers all the three strands for the relevant level. Year 4 conclusions are summarised below as these have greater relevance to this paper.

The 2016 study concluded that Year 4 students generally have lesser opportunities to learn technology - less than 50% teachers and students reported that TE lessons were provided. Additionally, as reported, Year 4 students are taught by classroom teachers who have limited formal or informal qualifications. In TE, a very low, nine percent of Year 4 teachers had any qualification or background to teach technology with an additional seven percent indicated that they had other informal experience with teaching technology. About 40-50% of Year 4 teachers agreed moderately when asked if they were satisfied with how they taught it and how confident they felt about assessing students' progress and achievement and supporting students' self-assessment and reflection on their progress. Only 38% of Year 4 teacher were aware of IoP and of those, 14% of Year 4 teachers used them often. Majority of teachers were aware of the Ministry run website Technology Online that provides resources for technology teacher.

Year 4 students performed well above average at TE objectives and Year 4 students were generally positive about technology. 73% of Year 4 students scored above the minimum score for Level 2 on the TE test. The data from the 2016 study offered contradictory results – students performed well in tasks despite having lesser opportunities to do technology or despite teachers' lack of formal PD in TE and lack of confidence in teaching TE. The results of the survey offer an interesting perspective on the nature of teaching and learning in TE that is so far not supported by research in TE. While the curricu-

Figure 2.3

Competencies and breakdown of each competency mentioned the New Zealand Curriculum



Created from The New Zealand Curriculum (p. 12-13), by Ministry of Education, 2007.

lum documents so far have related to content in TE in compulsory school settings, it is necessary to recognise the importance of key competencies and soft skills in learning TE.

Competencies and TE

The vision of the New Zealand curriculum (Ministry of Education, 2018a) is "*Young people who will be confident, connected, actively involved, lifelong learners*" (p. 7). The vision is operationalised through defining key competencies that schools and teachers should focus in addition to the academic goals. The key competencies in the New Zealand curriculum are thinking, using language, symbols and texts, managing self, relating to others, and participating and contributing (Ministry of Education, 2018a). These are further elaborated in Figure 2.3. The competencies are derived from a project by Organisation for Economic Development (OECD) and adapted to the curriculum after multiple rounds of consultation to make them specific to New Zealand context (Hipkins & New Zealand Council for Educational Research, 2018).

The key competencies in the New Zealand curriculum are also in alignment with what are labelled as "21st century skills". This term is promoted by a non-governmental organisation called 'Partnership for 21st century learning' that lists learning and innovation skills as creativity and innovation, critical thinking and problem solving, communication and collaboration as skills most important in the 21st century. The list further extends to life and career skills – flexibility and adaptability, initiative and self-direction, social and cross-cultural skill, productivity and accountability, leadership and responsibility (Battelle for Kids, n.d.). As mentioned by de Vries (2017), the movement towards incorporating 21st century skills greatly benefited the status of TE worldwide.

In this study, terms like "competencies", "skills", "dispositions" are referred to as "behaviours" in line with the argument by Claxton et al. (2011). Claxton et al argued that the aim is not to teach skills/competencies/dispositions in isolation but instead for it to become a way for students to behave. The curriculum recommends the incorporation of these behaviours in all learning areas so that students get opportunities to practice and express these behaviours. TE, a learning area in the New Zealand curriculum, lends itself extremely well to the learning, practice, and expression of these competencies (Te Kete Ipurangi, n.d.-b). An important aspect of how they emerge is the way that technology is taught and the pedagogical approaches that are involved in classroom practice.

2.2.3 Teaching technology

While there are many ways of teaching TE, for example guided inquiry, Makerspaces (J. P. Williams, 2017), Problem-based/Project-based learning, STEM, Project-Based Learning in STEM, I focus on the three most common ways – Inquiry learning, STEM, and PBL.

Inquiry learning

Inquiry learning has been around since the 1980s at least. Some believe inquiry learning to have originated with Dewey (for example, Crawford (2000) and Lazonder and Harmsen (2016)). Inquiry learning was designed with the aim to offer an opportunity for students to participate in an authentic scientific practice of pursuing answers to meaningful questions through use of procedures that are designed with thought and evaluated (S. J. Magnusson & Palincsar, 1995). It was built on the constructivist view of learning (Crawford, 2000) that students construct their knowledge through their mental activity (Driver et al., 1994). Using this approach, students confront authentic and meaningful experiences that they get to discuss with others (S. J. Magnusson & Palincsar, 1995). According to Llewellyn (2013), inquiry learning can be enacted through four levels: demonstrated inquiry, structured inquiry, guided inquiry, or self-directed inquiry. In the first two levels, teachers play a significant role in the inquiry learning process while guided inquiry requires teachers to act as facilitators to the student learning. In self-directed inquiry, students enact a completely independent inquiry. S. J. Magnusson and Palincsar (1995) proposed a model for planning and enacting guided inquiry in the classroom. The model had five steps that are cyclical - engage, investigate, describe relationship, construct/revise explanation, and report findings. While initially inquiry learning was developed and used in the field of science education, it has been extended to other subjects (Grant et al., 2017; Palupi & Subiyantoro, 2020).

Researchers conclude that inquiry learning improves students' science learning in comparison to direct instruction methods (Estrella et al., 2018; Furtak et al., 2012; F. Jiang & McComas, 2015). Additionally, some research also finds an improvement in students' critical thinking, logical reasoning, and problem solving skills (Fuad et al., 2017; Prayogi et al., 2018). In a meta synthesis of past meta synthesis, R. D. Anderson (2002) proposed that inquiry learning produces positive outcomes for the students. However, he qualifies this conclusion by mentioning that inquiry learning is defined differently by different educators, researchers, and teachers and could refer to different teaching practice by different teachers (R. D. Anderson, 2002). Other researchers agree that there is inconsistency in how terms are used in inquiry learning (F. Jiang & McComas, 2015; Lazonder & Harmsen, 2016). Capps and Crawford (2013) concluded in their research study in the USA that science teachers believed to be teaching science through inquiry learning, were not doing so. In their study, Capps and Crawford (2013) argue for educators and researchers to define inquiry learning so that the PD given to the teachers is meaningful. However, the literature agrees on some common elements of inquiry teaching: student-centred approach to learning, asking and pursuing answers to questions that can be posed by teachers or by students, and evaluation of evidence.

Through inquiry learning approach, TE can be taught as structured inquiry, guided inquiry or self-directed inquiry for older students of TE. Teachers can discuss the brief and guide students based on their specific needs. Students can be guided through the different lessons based on the AOs that the teacher targets. An effective TE lesson integrates all three strands across the unit and teacher focusses on four types of knowledge while planning the lesson: procedural, conceptual, societal, and technical (Moreland et al., 2001). Moreland et al. (2001) defines procedural knowledge as knowledge about how to do something and ways to do it including the timing. For example, know how to do a survey for developing the brief or how to measure using different instruments. Conceptual knowledge refers to the knowledge the student needs to know that are key to the technological practice (ibid). For example, concept of ergonomics and factors that affect it, or knowing about tolerances in measurement. Societal knowledge refers to relationship between technology and society (ibid). For example, knowing about the effect of impact of design of scissor on left-handed people, or availability of a certain resource in a specific country. Technical knowledge refers to knowledge needed to carry out the technological practice safely (ibid). For example, knowing how to use a drill or sewing machine. Some aspects of the TE lessons may need demonstration by the teacher while some could be done independently by the students. The inquiry process aligns with the design process of technology and there is great synchronicity in using the inquiry approach with TE. Research studies has been carried out in teaching TE through inquiry learning or as part of integrated STEM (Abdurrahman et al., 2019; Rached & Grangeat, 2021). STEM is discussed in the next section.

Teaching TE through STEM

STEM is an acronym of Science, Technology, Engineering, and Mathematics and signals an opportunity of learning through a programme that connects these four subjects. Caldwell and Pope explain:

> STEM education is a means of offering coherent learning experiences that make connections between the individual curriculum subjects explicit and enhances learning in all of them. A STEM approach puts children at the centre of learning, helping them to use and develop skills across the curriculum in meaningful ways (Caldwell & Pope, 2019, p. 1).

Teaching and learning of STEM subjects is high priority globally (D. Bell, 2016; J. M. Ritz & Martin, 2013). Nations are seen to need to strengthen their economies through innovation and they need future workforce in these subjects (J. M. Ritz & Martin, 2013; J. P. Williams, 2011). Furthermore, students seem to be performing low on STEM subjects based on their mathematics and science tests (J. M. Ritz & Martin, 2013) which necessitates a focus on the STEM subjects in schooling. An additional reason for the focus on STEM globally is that it is believed that STEM literacy is needed for citizens of the 21st century (ibid). STEM education has been championed by political, governmental discourse and by educational and professional organisations (ibid).

Additionally in their review of STEM literature worldwide, J. M. Ritz and Martin (2013) suggest that some teachers teach STEM subjects individually as science, technology, engineering, and maths and maybe, plan for integration between two or three of the subjects. Other educators (Morrison et al., 2009; J. G. Wells, 2016) argue for teaching STEM in an integrated approach by integrating all the four subjects together and designing activities that will authentically integrate four in the classroom. Integrated STEM is considered necessary as studies reported that students designing technology and engineering projects applied mathematics and science to a limited extent (Fan & Yu, 2017). An integrated approach is believed to help integrate conceptual knowledge (Fan & Yu, 2017) and higher order thinking (Fan & Yu, 2017; J. G. Wells, 2016). Every country has a different approach to STEM education (J. M. Ritz & Martin, 2013). Some countries have integrated Arts into STEM to have a STEAM approach.

Research in STEM demonstrates that integrative approaches improve student motivation in STEM as well as student achievement in the STEM subjects (Becker & Park, 2011). In the research reviewed, students show greater increase in factual knowledge and deeper and complex understanding of concepts (Riskowski et al., 2009). However, a meta-analysis conducted by Becker and Park (2011) cautions about the subject combination integrated in STEM as some subject combinations do not show as much gains as others. The meta-analysis also concluded that integrated approaches work better in lower years as compared to higher education (Becker & Park, 2011).

In a study of TE educators around the world, it was found that the participants were integrating TE in STEM (J. M. Ritz & Martin, 2013). However, there is confusion of the "T" in STEM. Some non-TE educators, take the "T" to mean using educational technology and not TE (for example, (Florida Department of Education, 2022)). There is no research of effectiveness of teaching TE through integrated STEM instead TE educators have debated on whether the focus on STEM is likely to benefit TE's status (J. P. Williams, 2011). PBL, is another approach similar to STEM that can either strengthen or weaken the place of TE in the school's curriculum.

Project-based learning

Blumenfeld et al. (1991) suggest PBL is a perspective and a framework:

> "Project-Based Learning (PBL) is a comprehensive perspective focused on teaching by engaging students in investigations. Within this framework students pursue solutions to non-trivial problems by asking and refining questions, debating ideas, making predictions, designing plans and/or experiments, collecting or analysing data, drawing conclusions, communicating their ideas and findings to others, asking new questions, and creating artifacts." (p. 371).

In a PBL approach, students are offered a project to complete and students work on the project with varying degree of independence. Blumenfeld et al. (1991) further explain that the project begins with a question or problem that can be designed by either the teacher, curriculum developer or student. The questions need to be broad enough so that the solutions can be varied. The final artefact needs to demonstrate student learning and could be in the form of videos, photographs, presentations, sketches, reports, and models (Holubova, 2008).

Project-based learning and Problem based learning are often, both, abbreviated as PBL and used interchangeably, but they are not the same. Project-based learning has an artefact as the end-product while Problem-based learning is primarily process focused and may or may not have an artefact (Helle et al., 2006; Kokotsaki et al., 2016). However, the execution of lessons in both approaches follow a similar path. In this thesis, project-based learning is abbreviated as PBL and problem-based learning will be referred to without any abbreviation. Both PBL and problem-based learning are situated in the domain of inquiry-based learning and are informed by the philosophical writings of Dewey (Brears et al., 2011). Integrated PBL or interdisciplinary PBL integrates two or more subjects and the subjects are taught using PBL. Instructional support provided is to support the extension of the project (Morgan, 1983).

In PBL, the creation of artefacts is essential as through this students construct their knowledge (Blumenfeld et al., 1991). Feedback from peers and other adults is also a critical aspect of PBL (Blumenfeld et al., 1991; J. P. Williams et al., 2007). The other important aspect of PBL is the realistic, contextualised project (Blumenfeld et al., 1991; Helle et al., 2006). Brears et al. (2011) argue that PBL can offer an opportunity to operationalise 21st century skills. When comparing the similarities between PBL as a teaching strategy and the design process of TE, there are many similarities that lend PBL to teaching of TE (A. Williams & Williams, 1997).

According to research reviewed, students following a PBL approach learnt the content better (Halvorsen et al., 2012; Kaldi et al., 2011; Karaçalli & Korur, 2014; Panasan & Nuangchalerm, 2010), retained the knowledge better (Karaçalli & Korur, 2014) and were more motivated with the PBL approach (Kaldi et al., 2011). Kaldi et al. (2011) also found that students had self-efficacy and better attitude towards their peers from different ethnic backgrounds. Halvorsen et al. (2012) found that PBL approach worked well with students from low socio-economic backgrounds.

TE can be integrated with two or more subjects when taught through the integrated PBL approach or can be taught individually in the PBL approach. Generally, students are grouped together to work on an initial brief after which the students research the context of the brief and work a plan to develop a technological outcome (A. Williams & Williams, 1997). The students then work together to make a prototype and reflect on their learning while doing the project (A. Williams & Williams, 1997). The teachers' role is to structure the initial brief and guide the students through the development of the technological outcome (J. P. Williams et al., 2007). It is also critical for teachers to not directly provide answers and instead to probe students' knowledge and reasoning and involve all students in dialogue (A. R. Putnam, 2001). There have been no specific studies that evaluate the effectiveness of teaching TE through the PBL or problem-based learning approach.

Which approach is used for teaching TE and the position of TE within these approaches are based on a number of factors. Outside the classroom, government policies, curriculum documents, school requirements, and wider educational community can dictate what is translated into the classroom. At the classroom level, teacher beliefs and knowledge can play an important role in the way TE is approached. The next section is focused on teacher beliefs and knowledge and their impact on TE teaching.

2.2.4 Teacher's beliefs and knowledge in Technology Education

Teacher's beliefs and teacher's knowledge are closely related (B. B. Levin, 2015). In the 1990s, various researchers offered clarifications on the difference between knowledge and beliefs (ibid). An often stated difference between the two is that belief is personal and subjective while knowledge is commonly agreed by members of the community (ibid). In this section, I start with reviewing teacher's beliefs, followed by teacher's knowledge.

Teacher's beliefs

Post 1980s, educational reform proponents and researchers started studying teacher's beliefs as playing an important role in the teacher's practice in the classroom (Skott, 2015). Clark (1988) explained how teacher's implicit theories can affect how they perceive, interpret, and judge and hence, on what they do and what they say. These implicit theories are complex and built over a period of time from life experiences including beliefs, values, biases and prejudices (Clark, 1988). F. Pajares (1993) claims that there is no agreed upon definition of teacher beliefs. Some research includes attitudes, prejudices, values as part of teacher beliefs (Skott, 2015). Definition of belief also impacts research on belief as participants and researchers may not look at a term in the same way (ibid). Empirical findings, hence, often contradict the effect of teacher beliefs on teacher practice (ibid). However, it is recognised that teachers' beliefs act as filter for interpretation (Fives & Buehl, 2012). In a systematic review of research on beliefs, Buehl and Beck (2015) found that teacher's beliefs influence their practice when those beliefs are visible in the practice. They concluded, based on review of contrasting studies, that beliefs and practice influence each other and strength of this relationship is dependent on the individual, context and the type of belief or practice that was being studied. They further reviewed studies for experienced and inexperienced teachers and found that some studies found more alignment between beliefs and practice when teachers were experienced and teachers whose beliefs are in flux are likely to have inconsistent practice (Buehl & Beck, 2015).

Beliefs about teaching include how teaching should be done, what methods are most effective, who is responsible for it (Fives et al., 2015). Generally, beliefs about teaching guides the classroom-level decisions that teachers make (ibid). In a systematic review, Fives et al. (2015) found that teacher's beliefs of teaching is around teacher-centred and student-centred models of teaching. Teachers can often hold opposing beliefs but research on beliefs about teaching can be quite muddled as research studies do not define the terms they use (Fives et al., 2015). Teachers beliefs' also inform their instructional strategies (Fives & Buehl, 2012). Rubie-Davies (2015) argues on the basis of research studies that while teachers in NZ believed formal, standardized tests did not offer much information about student learning and hence, they did not use them in the classroom; while in China, teachers belief that students were accountable for their own learning meant that they tested students with formal, standardized tests to know how much effort students were putting into learning the material. Rubie-Davies (2015) also argues that teacher's behaviour in the classroom based on their beliefs about responding to students' social and emotional needs determines the classroom climate and hence, student learning. Teacher's beliefs and conceptions of assessment can also influence their practice in regards to assessment (N. Barnes et al., 2015). After reviewing research around teacher's beliefs about assessment, (N. Barnes et al., 2015) conclude that more experienced teachers found it easier to use formative assessment processes although most teachers agreed about its desirability. Most teachers in various studies believed it their responsibility to offer feedback in formative assessment. The authors remark that culture plays an important role in teacher's beliefs around assessment.

Teacher's beliefs about the subject and their conceptions of the subject are important aspects of their practice. Chen et al. (2015) describe the beliefs about a subject as the beliefs of the teacher about the nature of the subject and knowing. Reviewing studies from research in science, Chen et al. (2015) conclude that teachers beliefs about the nature of the subject determine how they practice it in the classroom although certain factors can create an incongruity between beliefs and practice. These factors are other teachers' beliefs, school context, self-efficacy of the teacher about teaching a subject, and amount of support provided to inexperienced teachers.

In the specific case of TE, there has been confusion about what technology stands for and the aims of teaching TE (Doyle et al., 2019). Teacher understanding of what TE means will influence how it is taught in the classroom (Dakers, 2005; Jones et al., 2013). Doyle et al. (2019) argued that in TE especially teacher beliefs about the nature of the subject and activity is necessary as there is no 'right answer' in TE and the TE's lack of explicitly defined content knowledge puts a lot of onus on the teacher to meet the aims of TE curriculum. A quantitative research in NZ among 900+ student teachers (those studying to become a teacher) found that they were positive about the importance of TE but conceptualised technology as computers (K. Lee et al., 2020). This could be result of general confusion between educational technology and TE (ibid). However, the student teachers recognised design as an important part of TE contrary to research carried out in the late 1990s (ibid). It seems as if some aspects of TE were becoming clearer and some aspects of TE remain muddled.

Teacher's knowledge bases

There is general confusion in what constitutes teacher's professional knowledge bases. While content knowledge and pedagogical knowledge was widely accepted as the main knowledge bases, in a widely quoted paper, Shulman (1986) introduced the concept of PCK as an additional type of teacher knowledge that is important in the classroom. PCK is defined by Shulman (1986) as "*... dimension of subject matter knowledge for teaching*" (p. 9) and "*... particular form of content knowledge that embodies the aspects of content most germane to its teachability*"(p. 9). He further elaborates that "*... also includes an understanding of what makes learning of specific topics easy or difficult...*" (p. 9). To summarise, Shulman's concept of PCK relates to how to teach a specific topic, different ways of representation within that topic, resources to be used to optimise the learning, and alternate conceptions and preconceptions students are likely to have about the topic. PCK is different than content knowledge or subject matter knowledge which refers to the knowledge that a professional in the field would have. More than just knowing the content of the field, content knowledge is also about knowing the organising principle and structures and understanding the rules and beliefs used by professionals in the field (Shulman, 1986). Often, research studies are likely to link the teacher's ability and motivation to have a dialogue to their PCK.

When Shulman proposed the idea of PCK, he identified three essential components: subject matter knowledge, pedagogical knowledge, and knowledge of context (Shulman, 1986). However, over a period of time, the concept of what constitutes a teacher's PCK has developed. In 2012, in a meeting of researchers in science PCK, known as PCK summit, a "Consensus Model" for professional teaching knowledge and skills, including PCK was developed (Chan & Hume, 2019). The Consensus Model was published by Gess-Newsome (Gess-Newsome, 2015). The knowledge categories in the model are assessment knowledge, pedagogical knowledge, content knowledge, knowledge of students, and curricular knowledge (Gess-Newsome, 2015). Together these are known as Teacher Professional Knowledge Bases (TPKB) (ibid). The next level has topic-specific professional knowledge which include knowledge of instruction strategies, content representations, student understanding, science practices, and habits of mind. Teacher's orientations and beliefs, prior knowledge, and context were filters or amplifiers that have an impact on the content and nature of a teacher's PCK (Chan & Hume, 2019; Gess-Newsome, 2015). The model then introduces two PCK. Personal PCK is the "*knowledge of, reasoning behind, and planning for teaching a particular topic in a particular way for a particular purpose to particular students for enhanced student outcomes*" (Gess-Newsome, 2015, p. 36). The second type is Personal PCK&S which is "*the act of teaching a particular topic in a particular way for a particular purpose to particular students for enhanced student outcomes*". The definitions make clear that personal PCK and PCK&S are context specific. The difference between the two is the skills aspect of teaching - not all teachers have the teaching skills to implement their knowledge (ibid). The last two levels in the Consensus Model refer to students and are student amplifiers and filters and student outcomes.

Chan and Hume (2019) claims that the Consensus Model was theoretical and not empirical. Student achievement was positively linked with content knowledge of the teacher in a study with 50 science teachers in USA (Gess-Newsome et al., 2019) as well as another quantitative study with 181 middle school physics teachers and 9500+ students (Sadler et al., 2013). However, the ways to measure PCK is quite varied different which could lead to different results. For example, while the study by Gess-Newsome et al. (2019) with 50 teachers mentioned above found that teachers with strong PCK were no more likely to affect student learning than those with weak PCK, the study by Sadler et al. (2013) with 181 science teachers measured one component of PCK and found a positive effect of measured PCK with student achievement. A drawback recognised of the Consensus Model is that it does not explain PCK's composition (Kind & Chan, 2019).

Another PCK summit in 2017 led to development of Refined Consensus Model (RCM) (Carlson et al., 2019). This model has five concentric circles of PCK - enacted PCK, personal PCK, the learning context, collective PCK, and professional knowledge bases. Enacted PCK is akin to personal PCK and personal PCK&S as defined by Gess-Newsome in the consensus model. Personal PCK in the RCM is then different and encompasses a "reservoir of knowledge and skills that the teacher can draw upon during the practice of teaching" (Carlson et al., 2019, p.87). Collective PCK is a collection of all subject teachers' contributions and is publicly held. The professional knowledge bases include content knowledge, pedagogical knowledge, knowledge of students, curricular knowledge, and assessment knowledge (Carlson et al., 2019). While the RCM model mitigates some drawbacks of the Consensus Model, it needs empirical backing as well.

In TE, Jones and Moreland (2003a) argued on basis of their three-year research in NZ that PCK had seven constructs: nature of the subject and its characteristics, conceptual, procedural, and technical aspects of the subject, knowledge of the curriculum, including goals and objectives as well as specific programmes, knowledge of student learning in the subject, including existing knowledge, strengths and weaknesses and progression of student learning, specific teaching and assessment practices of the subject, understanding the role and place of context, classroom environment and management in relation to the subject. While Rohaan et al. (2010) argues that there are six-technology specific knowledge aspects, that can be categorized into three domains: Subject matter knowledge, PCK, and Attitude. Subject matter knowledge has the aspects: general subject matter knowledge and concept of technology. PCK has the aspects knowledge of pupils' concept of technology, knowledge of pupils' pre and misconceptions, knowledge of pedagogical approaches and teaching strategies for TE. Attitude includes the aspects of attitude towards teaching technology and confidence in teaching technology. Irrespective of how it is classified, multiple research studies have found positive relation between enhanced PCK and student learning in TE (Fox-Turnbull, 2006; Jones & Moreland, 2004; Stein et al., 2002). In a Dutch study of 354 primary teachers, Rohaan et al. (2012) found that subject matter knowledge influences PCK as well as teacher's self-efficacy.

In relation to knowledge and beliefs, there is much debate of whether teacher beliefs are part of PCK (Doyle et al., 2019). A theoretical model was proposed by Doyle et al. (2019) which depicted the intricacies of a TE teacher's practice. The model included beliefs on one side and knowledge on the other with enacted practice in the centre. Teacher beliefs include beliefs about nature of TE, beliefs about goals and purposes of TE, and beliefs about teaching and learning of TE. Knowledge includes PCK, topic specific professional knowledge, and teacher professional knowledge bases. Situational amplifiers and filters such as school context, time, resources, interruptions can affect the teacher's enacted practices. Systemic amplifiers and filters such as curriculum demands versus the teacher's aspirations, standard practices of the school or culture also affect a teacher's enacted practice.

2.2.5 Section Summary

In this section, the focus was on Technology Education. The section explained how TE is viewed around the world and then focused on TE in NZ. TE in NZ was explained in detail as it is the context for the study. It is to be noted that TE in NZ was introduced in 1995 and the curriculum was revised in 2007 and 2017. TE's introduction and subsequent revisions in the curriculum along with the change in government's focus through these years indicate the struggles TE has had to be established firmly as a learning area in compulsory education in NZ. Surveys regularly conducted by the government continue to show that while students enjoy TE lessons, they have limited opportunity at primary level to engage in them and they are taught by teachers who are no longer offered TE specific professional development in schools. The TE curriculum is well defined through two documents – the Technology curriculum and the Indicators of Progression (IoP). TE is closely linked with competencies in the NZC – and the competencies can be developed through TE practice. There are various approaches to teaching TE, and this study focuses on three most cited approaches in literature – Inquiry learning, PBL, and integrated STEM approach.

Teacher beliefs and teacher knowledge in TE are complex areas of studies and contradictory research results from different studies around the world in different subjects can be quite confusing. However, in TE all the confusion is multiplied manifold due to the relative newness of TE as a learning area as well as the nature of the subject itself. Integrating teacher beliefs and knowledge in one model for TE, Doyle et al. (2019) details all the critical components of teacher beliefs, teacher knowledge, situational and systemic amplifiers and filters that can have an effect on teacher's enacted practice in TE. The next section is focused on IFA in TE.

2.3 Interactive formative assessment in technology education

Leading from the previous two sections on dialogue and TE, this section will focus on dialogue in TE. The research on any kind of talk or interactions in TE is quite limited to date. As the focus is on dialogue in formative assessment specifically, first the literature related to formative assessment in TE will be reviewed, followed by the literature for dialogue in TE. This leads to the next two sections on the theoretical framework and research questions for the study.

2.3.1 Formative assessment in technology education

As reviewed before, the key aspects of formative assessment are open questioning and feedback from the teacher. Formative assessment lies in a continuum from planned and formal to transient and informal. However, research literature specifically for formative assessment in TE is quite limited. TE is a learning area which cannot be taught solely by rote since it requires students to come up with multiple creative ideas to meet the brief and requires them to exercise judgement as they research, plan, and develop their technological outcomes (Black, 2008). The major literature for formative assessment in TE are Black's Black Box booklets (Black, 2008), several research projects conducted by Moreland in NZ (Moreland, 2003a; Moreland & Cowie, 2009; Moreland et al., 2007;

Moreland & Jones, 2000; Moreland et al., 2001) and Fox-Turnbull's research in NZ (2006) (Fox-Turnbull, 2003). These are now reviewed.

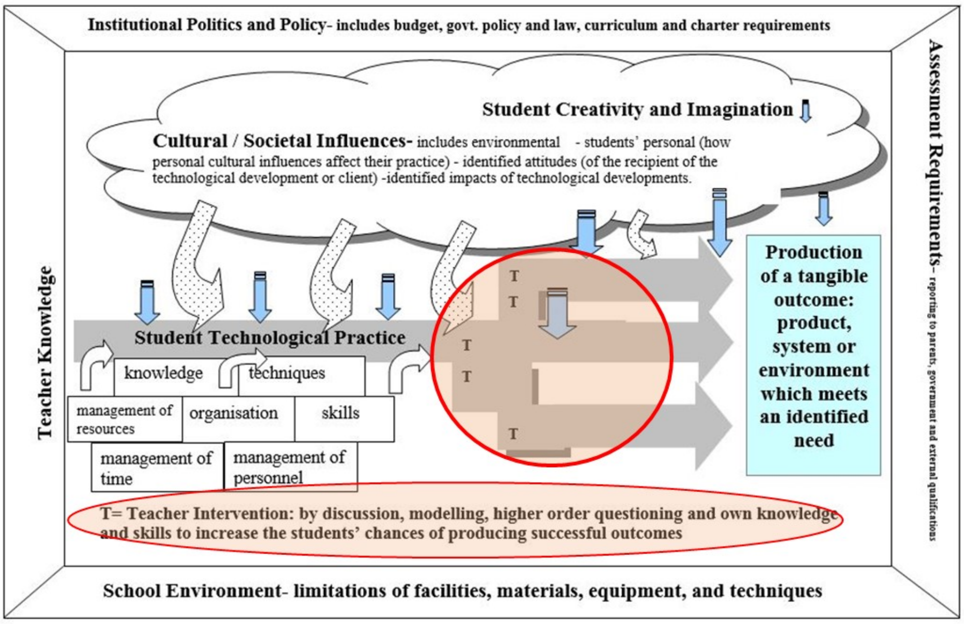
According to Black and Wiliam (2009) and Leahy et al. (2005), there are five key strategies of formative assessment. These five key strategies are clarifying learning intentions and success criteria, engineering effective classroom discussions and other tasks for eliciting student understanding, providing feedback that moves learners forward, activating students as instructional resources for one another, and activating students as the owners of their own learning (ibid). Dialogue and discussion need to be used as the main method to formatively assess students (Black, 2008; Moreland et al., 2007). By asking rich questions, supporting participation by all learners, and encouraging discussion the teachers can interact with students in a meaningful way (Black, 2008). Black (2008) recommends teachers to share complex questions and change from the practice of only asking closed questions. He further stated that meaningful, specific feedback is a form of dialogue as well. Effective formative assessment encompasses the "*multidimensional nature of technology, and help students build continuity and coherence between ideas and actions over time*" (Moreland et al., 2007, p. 38) and IFA in TE "*invoke multiple modes such as drawing, modelling and examination of real artefacts, not just talk, for communicating and developing ideas*" (Moreland et al., 2007, p. 38). The main takeaway from the key researchers in the field of TE is that formative assessment in TE occurs through dialogue and discussion supported by drawing and modelling – effective formative assessment is mainly interactive.

In a study conducted with four TE teachers in Sweden, the analysis of teacher's assessment practices show that teachers conducted formative assessment in dialogue with students (Fahrman et al., 2020). In research studies conducted by Moreland (Jones & Moreland, 2003b; Moreland, 2003a) that spanned nine years and over 30 primary teachers, Moreland et al. (2007) summarised that teachers conducted formative assessment through dialogue and discussion using multiple modes in addition to talk such as modelling and manipulating of materials. Planning was a key practice through which the IFA between teacher and students became more effective and IFA helped students to build connections and make the learning more coherent. However, a research study in Sweden indicated that formative assessment is not planned beforehand (Hartell, 2013). Hartell (2013) concluded that in her research study conducted in Sweden's primary schools, teachers looked for "*glimpses in the eye*" for students' understanding of what was being taught and did not document student learning in any meaningful way for students or (future) teachers to use the information to help students progress in TE.

In NZ, Fox-Turnbull (2006) discussed a model of student technological practice that

Figure 2.4

Model of student technological practice



Emphasis added. Reprinted from The Influences of Teacher Knowledge and Authentic Formative Assessment on Student Learning in Technology Education by W. Fox-Turnbull, 2006, International Journal of Technology and Design Education, 16(1), 53-77. Copyright 2006 by Springer. Used with permission.

included a discussion of formative assessment. The complete model is shown in Figure 2.4. Not all parts of this model are of concern for this study; the relevant portions are highlighted in red. The model shows that students' technological practice is aimed at developing a technological outcome that meets a need or addresses an opportunity of a consumer. As students worked on developing the outcome, teachers intervened through the process of formative assessment by providing feedback on the knowledge and skills at appropriate time and using an appropriate method. In the figure, the highlighted parts indicate the teacher intervention in the process of students' technological practice. The teacher's formative assessment practice, thus, guided the students' development of a technological outcome. While presenting the model, Fox-Turnbull (2006) explained that two issues drove the formative assessment process in a technology classroom – when to intervene (timing) and how to intervene (method). Hence, teacher intervention was to be timed so that the student did not lose motivation or run out of time. Fox-Turnbull further proposed that teacher intervention could take the form of discussion, higher order questioning and modelling.

Fox-Turnbull additionally mentioned the various constraints to an authentic technological practice. These constraints are institutional politics and policy, school environment, and teacher knowledge. Limited teacher knowledge and teacher PCK were identified as a constraint for effective formative assessment practice in Moreland's research studies as well (Moreland, 2003a; Moreland & Cowie, 2009; Moreland et al., 2007; Moreland & Jones, 2000; Moreland et al., 2001). In the next section, discussion and dialogue conducted in the context of TE will be discussed.

2.3.2 Dialogue in technology education

While the number of studies on dialogue in TE is limited, three studies are reviewed below. Each of the studies focused on different aspects of dialogue. The study by Fox-Turnbull (2016) in NZ introduced the concept of intercognitive conversations, the study by Hamilton (2007) revealed some important actions of teachers to enable dialogue, and a UK based study by Stables et al (2016) revealed question types that can help TE students if they were stuck.

In Fox-Turnbull's research (2016), she introduces the term "intercognitive conversations" to include "*all conversation in which all participants gain new understandings through participation and openness to new ideas*" (p. 37). Intercognitive conversations, thus, refers to a dialogue where every participant has learned something. She further classifies intercognitive conversations into two types: convergent and divergent. Convergent growth conversations are dialogue where all participants grow in the same field of learning and divergent growth conversations are dialogue where all participants grown in different fields of learning. For example, the students learn about the melting point of different materials and the teacher learns about alternate conception that the student holds that the melting point is constant for a material. Teachers learn by talking to students about their alternate conceptions and can plan further lessons or interactions based on what they learn from the students. From Fox-Turnbull's research, the key takeaways for dialogue in TE are the concept of intercognitive conversations. Teachers and students can be having intercognitive conversation where each of them is learning something different during their dialogue.

Sensitivity and responsiveness by the teacher during the dialogue is important for student learning and making thinking more explicit in the classroom (Hamilton, 2007). In a conference paper Hamilton (2007) presented a research study that derived data from a wider 10-country European study. The data from two different classrooms for ages 11 and 14. Hamilton mentioned the success of dialogue in the success of the TE unit. The classroom used ground rules for collaboration for working with each other. A safe environment where students felt they could take risks and offer ideas without fear was critical for dialogue. Hamilton concluded that dialogue helped teachers enhance their own learning and take more risks in the classroom. The finding about teachers learning during the dialogue is in line with Fox-Turnbull's (2016) intercognitive conversations. The concept of creating a safe environment and ground rules for collaboration have been mentioned in section 2.1.1 in the review of research on increasing dialogue in the classroom.

Researchers Stables et al. (2016) explained the development of an artificial-intelligence (AI) design mentor in TE. In the initial stages of the research project, they analysed the dialogue between teachers and students in multiple TE classrooms. To develop the AI, they classified the interactions between teachers and students and arrived at three overarching categories of open-ended questions that teachers ask: mind-reading questions such as "*What are you designing?*", managing questions such as "*How are you going to make it work?*", and mentoring questions such as "*How do you think it is going?*" The idea behind the AI is to drive students' self-assessment. The researchers also mentioned that using more speculative language like "What if", "How could" allows for effective dialogue. This research study offered some insights on the questions that could be part of formative assessment dialogue between the teacher and students in TE.

The review of literature in dialogue and formative assessment in TE leads us to the conclusion that dialogue between teacher and student is a key method to conduct formative assessment. Key educators and researchers in both formative assessment and in TE recommend that teachers need to plan their questions in advance and share good questions among each other. This leads us to an identified problem statement of needing a planned framework of questions for TE that can aid TE teachers in carrying out effective dialogue in the classroom with students.

2.4 Technology observation and conversation framework

Interactive Formative Assessment (IFA)in TE is likely to be spontaneous and immediate, as teachers cannot predict the student thinking they are likely to encounter in the classroom. As seen from the NMSSA survey (Ministry of Education and NZCER, 2016), majority of primary teachers do not have a qualification in teaching TE and around half of them are not confident in teaching and assessing TE (ibid). It is likely that IFA cannot happen spontaneously in the classroom (Shavelson, 2006). Therefore, a valuable formative assessment tool for the teachers could be through providing a planned framework of high-cognitive questions.

There are three requirements for this planned framework. The first requirement is that the resulting interactions are divergent intercognitive growth conversation which means both the teacher and students learn from the resulting dialogue. High-cognitive questions can engage the student in dialogue and in answering these questions, students could be guided to the next step in learning (B. Bell & Cowie, 2001). Questions could carefully, and non-judgementally, expose to the students the gaps in learning. While engaging in dialogue, teachers are made aware of student thinking in technology that will help in preparing future lessons and units. The second requirement is having NZ curricular objectives incorporated. Only 38% of Year 4 teachers in NZ are aware of indicators of progression (IoP) used to gauge student progress in technology (Ministry of Education and NZCER, 2016). This lack of knowledge could be because of lack of training opportunities provided to teachers and the generalist approach of primary teachers where there is limited time in Initial Teacher Education (ITE) for each learning area. By incorporating curricular objectives in TE, teachers get exposure to the language and content of the curriculum. The third requirement for the framework is around feedback. As mentioned in section 2.1.4, feedback is an essential part of formative assessment (Black & Wiliam, 1998) and teachers with low content knowledge or PCK tend to give feedback on social and managerial tasks that students perform rather than on technology (B. Bell & Cowie, 2001; Jones & Moreland, 2005; Moreland et al., 2001). Given the importance of the 21st century skills and key competencies in the NZC to technology practice, the behaviours should be integrated in the planned framework in such a way that they integrate with their application in technology rather than be generic.

To summarise, the three goals of the planned framework for planning IFA are divergent growth conversation cues in the form of high-cognitive questions to improve student learning, integrating technological knowledge from the NZC to improve teachers' content knowledge, and integration of behaviours in the conversation contextualised to technology.

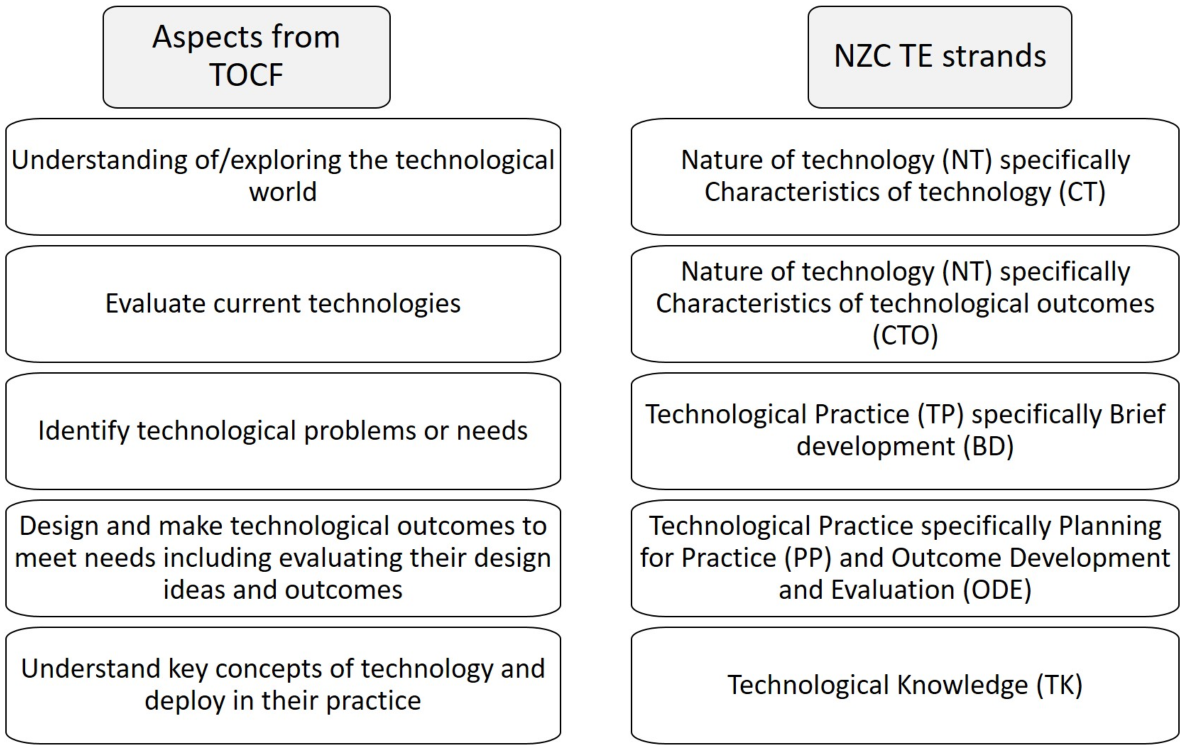
Technology Observation and Conversation Framework (TOCF) (Fox-Turnbull, 2018) is designed for a technology classroom and provides a guide to the teacher for things to notice and conversation cues and higher order questions that develop students' learning in technology. The TOCF was recognised as a good fit for the requirements of a planned framework of questions for IFA. The TOCF was designed for students for ages 4–6-years. Fox-Turnbull mentions that the main purpose of designing the TOCF was to develop teacher's content knowledge and teacher's technological content knowledge. In this research study, the plan is to modify the TOCF so that it can be used as formative assessment tool by primary teachers in NZ teaching TE.

2.4.1 Curriculum alignment in TOCF

TOCF is in a tabular form where the rows represent the technology aspects derived from the NZC. The columns focus on behaviours in technology and the cells of the table have a series of observation markers and suggestions for scaffolds. Scaffolds are in the form of language the teacher can use, questions to ask that are meant to initiate an intercognitive conversation. The framework as designed by Fox-Turnbull is attached in Appendix A.

Figure 2.5

Correspondence of the aspects from original study to strands from NZC



In the TOCF, the technology aspects have been derived from the study of the TE curriculum in three countries NZ, England, and Sweden. After analysing the three curricula, five aspects were identified. They are: understanding of/exploring the technological (made) world, evaluate current technologies (communicating ideas about the made-world), identify technological problems or needs, design and make technological outcomes to meet needs including evaluating their design ideas and outcomes (contributing to the made-world through making and construction in a range of areas), and understand key concepts of technology and deploy in their practice. The five aspects of technology shown in TE correspond to the three strands of TE in the NZC as shown in Figure 2.5. the aspects from TOCF relate to the technology strands and components in the NZC. Hence, the questions from TOCF are likely to align to TE curricular objectives in NZ.

2.4.2 Student behaviours in TOCF

The nature of TE sets it apart from other learning areas since it combines practical and academic skills while students work towards the development of a technological outcome. The problem-solving nature of technology lends itself to an holistic learning experience for students that integrates academic knowledge, practical skills and expression of competencies and values (Snape & Fox-Turnbull, 2011b). As mentioned in section 2.2.2, key competencies from the NZC and 21st century skills are behaviours that students practice in the whole unit in technology education and are implicit to the design process (Hipkins, n.d.; Snape & Fox-Turnbull, 2011b). Fox-Turnbull (2018) identifies these five main behaviours as key behaviours that teachers can focus on to promote learning in technology: resilience, reflection, transference, flexibility and sophistication, and socialisation and they are defined in Table 2.2.

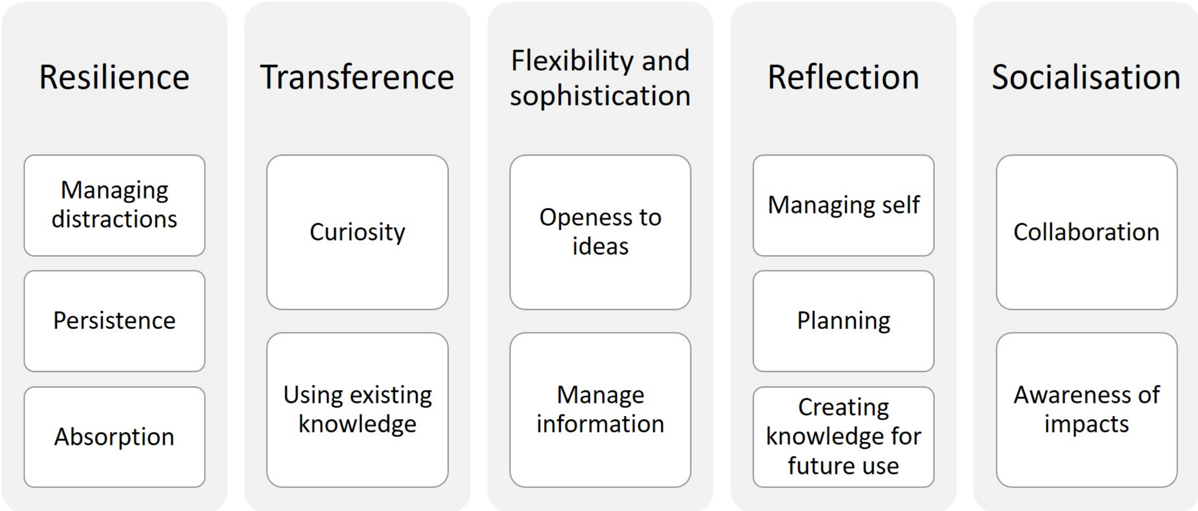
Table 2.2
Definitions of the five behaviours in TOCF (Fox-Turnbull, 2018)

Term	Definition
Resilience	includes capabilities of perseverance especially after initial failure, managing distractions from peers, other activities and people around them, and absorption in any given task.
Reflection	describes the strategic and self-managing aspect of learning and includes the planning and anticipating of needs and potential issues, and distilling information for potential future use.
Transference	includes making links to technologies experienced or seen, and experiences undertaken previously such as using existing cultural knowledge and experiences.
Flexibility and Sophistication	indicate a depth to understanding as well as an openness to new and potentially strange ideas. It involves use of reasoning to evaluate and distil information received in order to understand what is learned from an experience.
Socialisation	identifies with the inherently social nature of technology and its huge physical, social and environmental impacts. Whether engaging in the use or the development of technology students will be interacting in a social manner. They may be collaborating with others to develop single or parallel technologies, they will experience interdependence, or the balancing of self-reliance and socialisation, as the need for resources and skills arise.

Figure 2.6 offers a visual representation of these behaviours and sub-behaviours. These behaviours derived from the key competencies in the NZC, are key to technology education in the classroom. While the aim of the NZC is to provide opportunities to

Figure 2.6

Behaviours in TE as defined by Fox-Turnbull



Created from Enhancing teachers' understanding of young students' learning in technology, by W. Fox-Turnbull, 2017, Paper presented at the PATT 34 Millersville University, PA, USA.

practice and express these behaviours, students cannot succeed in technology education without the presence of these behaviours. For example, without being able to manage distractions, to become absorbed in the task and persevere - the behaviour of resilience, the student would give up when designing technological outcome when first encountering distractions or failure.

To summarise, the rows of the TOCF are the technology aspects or strands and the columns are behaviours. The cells of the TOCF are open, high-cognitive questions that teachers can ask the students. The cells also have observation cues and statements that the teacher can make in response to students' replies. Examples of questions from TOCF are mentioned below and demonstrate how the strand and behaviour are integrated in the open, high-cognitive question.

- If you / they were to redo this or make improvements, what changes should you/ they make? Why? (*Strand: Technological practice and Behaviour: Reflection*)
- What ideas did you change after talking to X/group? (*Strand: Technological practice and Behaviour: Socialisation*)
- What have we already learned that will help us with this design? (*Strand: Technological knowledge and Behaviour: Transference*)

Fox-Turnbull (2018) used the TOCF with teachers teaching with 4-6-year-olds across three countries – New Zealand, England, and Sweden. Teachers working with the framework stated that their understanding of technology education was deepened. TOCF also aided their teaching of technology and gave them insights into behaviours across aspects of technology. The teachers believed that the TOCF also helped them recognise the importance of intercognitive conversations, and that the framework helped them deepen student learning through high-level questioning, reflection, and collaboration. Based on the study of TOCF and the conclusions of the study across three countries, the selection of TOCF as the planned framework of questions for formative assessment seemed prudent.

2.5 Chapter summary

This chapter started with definition of dialogue and argued for the imperative for dialogue in the classroom based on evidence from multiple research studies. It reviewed literature on benefits of using dialogue in the classroom and the barriers to implementation of the dialogue. Dialogue for purpose of formative assessment is the focus of this study and the chapter then defined formative assessment with special focus on IFA which is where dialogue is used as formative assessment. Teacher's use of open questions that are also high-cognitive can help to increase the dialogue in the classroom. These questions need to be planned beforehand and shared among teachers as these types of questions are difficult to formulate on-the-fly. There are two models for IFA in literature reviewed in this chapter. The two models essentially focus on two main aspects: eliciting student knowledge and teacher's feedback. The research on formative assessment is extensive and mostly positive but there is paucity of research on IFA. Available research studies showed that IFA was complex, challenging, and demanding for teachers. Studies showed that teachers need to use the information from the students by giving them meaningful feedback for the IFA to be effective. However, there is not much other insight from the literature about IFA.

The context of this study is Technology Education (TE). TE is a subject that is taught in few countries as a mandatory subject during compulsory schooling. Research on TE shows that there are still gaps in understanding of the subject and teaching TE. In New Zealand, the last survey in 2016 in TE indicated that most primary schools lack adequate facilities or expertise to teach TE. Key competencies in the NZC are intimately linked with TE practice. Referred to as behaviours in this study, TE practice requires as well as improves certain behaviours in the classroom. Teacher knowledge and beliefs in TE affect teacher's enacted practice.

Formative assessment in TE is mainly carried out through dialogue with students. IFA in TE is prominent in literature as suggested method of formative assessment. However, there is a significant gap in the research literature on IFA in TE. There is not much known about the formative assessment process in TE, teacher's beliefs and knowledge that help them conduct IFA effectively in the classroom, or how student learning is affected by formative assessment in a TE classroom. To study IFA, I used a framework called the Technology Observation and Conversation Framework (TOCF) (Fox-Turnbull, 2018). The TOCF aligned with technology curriculum objectives as well as behaviours from the NZC. The modified framework is called the Questioning Framework for Technology - Primary (QFT-P). The implementation of the QFT-P and the gaps in the research literature influenced the formation of the research questions.

2.6 Research questions

The plan was to implement QFT-P as a formative assessment tool. The teachers would use the QFT-P and have formative assessment dialogue with students. As the QFT-P has not been used in a class with students of higher age group, my aim was to extend the TOCF to a higher age group (8-12 year-old) and align the TOCF with the IoP and the technology curriculum in NZ. The analysis of the dialogue would, hopefully, lead to insights about IFA in TE.

Main research aim: To study Interactive Formative Assessment in a primary, technology classroom

Research questions:

- What insights can be gained about Interactive Formative Assessment in Technology Education through an analysis of teacher-student dialogue?
- How do teachers' beliefs and knowledge impact Interactive Formative Assessment in Technology Education?
- What influence does Interactive Formative Assessment have on student learning in Technology Education?

Chapter 3

Methodology

> Scientific principles and laws do not lie on the surface of nature. They are hidden and must be wrested from nature by an active and elaborate technique of inquiry (Dewey, 1920, p. 32).

Methodology chapters often follow the literature review chapters as if to imply that the gap is identified first and then the appropriate methodology is identified. However, considering that the paradigm of the research is defined as the lens through which we view the world (Kivunja & Kuyini, 2017), it is unlikely that the paradigm of the researcher does not affect which questions they ask or which literature they identify as worthy of study. For me, my way of viewing the world dictated which research questions I found worth-while to study for this doctoral research.

A paradigm consists of four elements: ontology, epistemology, methodology and axiology (Lincoln & Guba, 1985). Ontology is concerned with the nature of existence, with structure of reality and epistemology deals with nature of knowledge (Crotty, 1998). Methodology describes the strategy or plan of action (Crotty, 1998) while axiology is concerned with the ethics, aesthetics, and religion of the research (Denzin & Lincoln, 2018). The paradigm in which I operate for this study compelled me to only look for research that is of practical value and would benefit teachers almost immediately – a pragmatic lens. The value that decided the methodology was wanting the teachers to have a voice in the research. Design-based research fulfilled that criterion. Each of these elements will be discussed in detail in this chapter.

This chapter introduces the participants, the two teachers - Jean and Sarah-Jane – as they taught technology education to 38 ten-eleven-year-olds. The methods for the study, the iteration rounds, the methods of analysis follow the background of participants. The final sections of the chapter describe the trustworthiness and ethics of this research.

3.1 Deweyan Pragmatism

The basis of this study's ontological and epistemological stance is Pragmatism based on the works of John Dewey. Dewey (1859-1952), an American philosopher and educator, expanded on the Pragmatist philosophy initially proposed by William James and Charles Pierce (Shook & Margolis, 2006). The paradigm proposed by Pragmatism requires re-defining some common words like "experience" and "knowledge". Hence this section will explain in some depth what Dewey meant by "experience" and "knowledge" and the research process.

Dewey believed that an organism and environment are intertwined (Biesta & Burbules, 2003) like time and space form a continuum. The organism continuously transacts with the environment trying to maintain balance. In transaction with the environment, an organism is continuously doing – this creates a response from the environment. For example, if you push against the wall, the pressure is felt in the palms of the hand. This doing and "suffering" the consequences of actions is called experience (Dewey, 1920). Thus, transactions between the organism and environment produce all (Deweyan) experience. All experience is real as the environment and organism are connected (Biesta & Burbules, 2003). There is no subject-object separation. Unlike in Phenomenology, where the phenomenon can be separated from the subjective bias of the researcher by bracketing (Crotty, 1998), there is no separation of the researcher from the context in Pragmatism. According to a pragmatic researcher, everything is real, and this reality is called transactional realism to distinguish it from the commonly understood reality of subject-object dualism (Biesta & Burbules, 2003).

There are multiple modes of experience – knowing mode, practical mode, ethical mode, aesthetic mode, religious mode are examples of some of them (Dewey, 1971). Dewey explains that knowing is the mode of experience that supports action (Biesta & Burbules, 2003). An organism desires action as it seeks a specific change in the environment. If the change occurs or does not occur, the organism now "knows" something. In a classroom, the teacher and the environment are intertwined and the teacher's actions that seeks to bring about some change results in knowledge for the teacher (Juuti & Lavonen, 2006). All teaching experiences do not lead to knowledge - only teaching that is reflected upon leads to knowledge (Juuti & Lavonen, 2006). Rodgers (2002) explains that reflection is not like other types of unstructured thinking but is rigorous and systematic. Dewey's explanation on the ontological and epistemological stance in Pragmatism is different from an interpretivist stance. In interpretivism, the situation being studied has multiple realities. We can "know" only through our version of reality (Kivunja & Kuyini, 2017) – thus, the nature of reality and nature of knowledge are both different through an interpretive lens than through a pragmatic lens.

The paradigm of the research also influences the research questions. The axiology of Pragmatism determines the research to be of practical and ethical value. The research questions in this study are intended to be of immediate use to primary, technology teachers and the gap in the existing literature was identified in the literature review. Ethically, teachers using a framework to ask questions of students in class is most likely to allow students to have more voice in the classroom and allowing longer dialogue is likely to help both students and teachers learn better in a technology education classroom. The next step after an explanation of the paradigm is to understand how Dewey explained the inquiry process.

To Dewey, inquiry was the process to solve problems that are experienced. Dewey explained the steps of inquiry as: "*(i) A felt difficulty, (ii) its location and definition, (iii) suggestion of possible solution, (iv) development by reasoning of the bearings of the suggestion, (v) further observation and experiment leading to its acceptance or rejection*" (Dewey, 2011, p. 72). The starting point for Dewey could be a "felt difficulty" - a situation that has been recognized as problematic (Biesta & Burbules, 2003). In this study, the problematic situation was recognised to be the struggle of primary, technology teachers to ask deep thinking questions to the students in the NZ classroom. A possible solution was recognised as the TOCF (Fox-Turnbull, 2018). In this study I sought to develop the TOCF to align with the NZ technology curriculum. In addition, I proposed using the modified framework, called the QFT-P, as a formative assessment tool for the teachers to gauge student learning.

The next step in the inquiry process according to Dewey is experimentation and this chapter explains the method of experimentation adopted in the study. Along with action, reflection is necessary since the distinction between trial-and-error method and process of inquiry is the thinking or reflection. Hence, the action of the methods is followed by the reflection of analysis. So, do the findings then represent the "truth"? According to Dewey, in changing a problematic situation that was indeterminate to a determinate one, the solution was an instrument and they do not have truth-falsity and the inference that the solution would work was "warranted" (Biesta & Burbules, 2003). The findings are then warranted assertions. The warranted assertions are instruments of new inquiries (Dewey, 1929) that can be "*used as an input in new inquiries, that is, as resources for dealing with the always unique problems with which educators are faced*" (Biesta & Burbules, 2003, p. 80).

As the warranted assertions are verified again and again by further research, they can provide a better and more refined view of the problem - but they can never be assumed to be unchanging in every single context. For instance, Finnish teachers cannot be transferred out of Finland to another country with the expectation of the same results as seen in Finland (Sahlberg, 2011). The findings of this study will be warranted assertions that can offer some views on the IFA process in a primary, TE classroom using the QFT-P in NZ.

As this research is to be used by the teachers, it is only logical to include them as an important voice in the research. One methodology that involves participants' voices is the DBR, described in the next section. Another methodology - participatory action research was considered for the study as it is philosophically similar (Cole et al., 2005) to Design-Based Research (DBR) as well as offers a stronger role to the participants by involving them in the research design process. The main differences between participatory action research and design-based research are that DBR involves development of a tool (in this study, the QFT-P) and action research involves the practitioners more extensively than DBR. However, as I am a foreign student, I was not sure of building the depth of relationship required for a participatory action research in the timeline for a doctoral study, I chose DBR as the methodology.

3.2 Design-based research

The term "design experiments" was coined by Brown and Collins in the 1990s (Collins et al., 2004). This term is synonymous with design research or DBR (Barab & Squire, 2004). It is a strong belief in design-based research that the context matters in terms of learning and cognition and cannot be considered as a variable or set of variables (Barab & Squire, 2004; Collins et al., 2004; The Design-based research collective, 2003). The context of the classroom along with all the resulting disruptions, interruptions, unplanned and planned activities all matter - removing parts of the context does not make sense in design-based research.

DBR aims to investigate an issue or implement an intervention in a specific context through multiple iterations and collaboration between the practitioner (teacher) and the researcher (The Design-based research collective, 2003). It aims to bring about an understanding and refinement of both practice and theory (Collins et al., 2004; The Design-based research collective, 2003). The research design is also aligned with teacher and researcher co-inquiry, whereby the university researchers and practising teachers work as co-inquirers and co-learners (Hennessy, 2014). It is important that the teachers and researchers work collaboratively, as the design-based methodology is based on iterations of user engagement, reflection, and modification. The teacher's contributions and reflections determine the direction of the iterations.

DBR, designed by and for educators, endeavours to enhance the impact and implementation of educational research into improved classroom practice (T. Anderson & Shattuck, 2012). It can illuminate the challenges of implementation, the processes involved, and the associated pedagogical and administrative elements (T. Anderson & Shattuck, 2012). DBR necessarily comprises multiple cycles, which involve several different design and research activities. Nieveen and Folmer (2013) divide these activities into three distinct phases: the preliminary research phase (which includes familiarization with the resources), the prototyping or development phase (which involves the iterations of trial, review and modification of the resources and pedagogy), and the summative evaluation phase (which includes the final iterative phase and the final teacher meeting). These three phases will be implemented through iterations of use, reflection, and modification of the framework, involving the teachers and their classes.

DBR was an appropriate choice for this study due to the pragmatic lens that places importance on the context with all its "messiness" and the collaboration with the teachers. Pragmatism with its ontological belief that the organism and environment are intertwined, is a perfect fit for a DBR. Through my research I was seeking to understand and refine the theory and practice of the use of a framework for teacher-student conversations in a technology classroom context. The use and subsequent modifications of the framework along with collaboration with teachers using the framework were key aspects to my research design. If busy teachers had limitations with using the framework, then the subsequent iterations were to fine-tune the format and content of the framework appropriately. The teachers in the study consented to trial, use, and reflect on the QFT-P as co-inquirers in the research process. The two teachers used the QFT-P in their primary classrooms. At first, both the teachers were provided with the entire framework that had been revised prior to commencement of the fieldwork stage to align with the NZC. As the teachers attempted to use the QFT-P in the classroom, the format was changed multiple times based on their feedback so that they could use the framework with more ease and fluency in the classroom. In line with DBR, the different iterations provided opportunities for the two teachers to experiment with different formats and gave me an opportunity to collect meaningful data that can add to the literature in TE. The data was gathered through multiple methods but before discussing the data collection methods, the background of the participants and the school is provided for context.

3.3 Field work

This section covers the approach to schools and introduces the schools, teachers and students who participated in this study. Any contact with the participants followed an ethics approval from the University of Waikato, Faculty of Education. The ethics are discussed in section 3.8. The schools that were invited to participate were selected based on convenience as there were no limitations on sampling by DBR or pragmatism.

3.3.1 Approach to schools

It was decided to record two full technology units at two primary schools. One school, in an urban area of New Zealand, was approached based on contact details provided by a parent. When I met the principal and showed them the framework, they informed me that the behaviours in the framework were in line with the values of the school and they were keen for me to conduct the research there. Once the principal expressed interest in the study, I met the Assistant Principal to show the framework and explain the study. The teacher, Jean (pseudonym), volunteered to be part of the study. I met Jean to obtain consent and discuss the logistics related to the study.

For the other school, an acquaintance knew of a teacher who was interested in participating in research. I met the teacher, Sarah-Jane (pseudonym), at the school and explained the research project. She was interested and asked me to speak to the principal. The principal agreed to let the teacher and the classroom participate in the research. I met with Sarah-Jane to get official consent and discuss the logistics.

I had contacted both schools early in the year before the schools opened for the academic year (in February). Other background details for the school and participants are provided in the next section.

3.3.2 The schools - Athena and Minerva

The two schools that agreed to participate in the research were from an urban area in New Zealand. The two schools are referred with the pseudonyms - Athena and Minerva. Both the schools were from Year 1-6 primary, public schools. Neither school had a technology centre or workshop. Most students in the school came from the surrounding areas that were low-income communities (classification based on information published by the Ministry of Education). Students stayed in a single classroom through the day and had one teacher who taught them all the subjects. At Athena, most classrooms had teacher aides (hired part-time by the school) and had a separate classroom for students with severe learning difficulties.

At Athena, the Assistant Principal had informed me that the senior classes were teaching all subjects through Project-Based Learning (PBL). Jean who had volunteered for my study, was also teaching through integrated PBL in Year 5-6 (10-11-years-old). The school encouraged this approach to teaching all the subjects and using the inquiry learning cycle to increase engagement with the students. The teachers were given supplies for the classroom for teaching through PBL since the students needed to make some product as a goal of the learning. All the teachers from senior classes planned the lessons together. They met once a week for planning the lessons. At the beginning of the term, they got together for 2-3 hours to plan the whole term. They allotted amongst themselves different duties like finding relevant worksheets, reading materials, sourcing materials, etc. During the term, the teachers exchanged quick feedback during lunch breaks and after school about how the lessons were progressing in their classrooms.

At Minerva, Sarah-Jane who was teaching a Year 6 (11-years-old) teacher taught technology through integrated Science, Technology, Engineering, Arts, and Maths (STEAM). She mentioned that she would have liked to use PBL approach for teaching all subjects but due to restrictions from the school, she could not do that. Over the year, some of the STEAM units could have science, technology, or arts as the focus. In contrast to Athena, Sarah-Jane did not receive any financial support from the school to conduct the STEAM lessons. She bought the supplies out of her own personal resources. The school also insisted on distinct maths, reading, and writing lessons through the day. Consequently, Sarah-Jane was allowed to conduct STEAM lesson once a week for half-a-day. Over my period of observation, through conversations with Sarah-Jane and casual observation of other classrooms, only Sarah-Jane conducted STEAM lessons. One other senior primary class teacher borrowed lesson plans and conducted some of the lessons. Over the multiple weeks, Sarah-Jane mentioned that she tried to convince other teachers to conduct STEAM lessons, but the other teachers did not agree.

3.3.3 The teachers - Jean and Sarah-Jane

Jean, who had taught at Athena for one year when I contacted her for research had three years of teaching experience and had taught in one other school before Athena. She had taught one unit of TE at a previous school. When I started the research at Athena, she had taught one unit using PBL. Jean had learned graphics design at school to which she attributed her knowledge of the design cycle. She said that she did not receive any professional development, formal or informal qualification in technology education besides that needed for her bachelor's (of teaching) degree. With her in the classroom,

Figure 3.1
Classroom at Athena

was a regular teacher aide for some special needs students. No consent was obtained from the teacher-aide and her work has not been included in this thesis. I worked with Jean through the second term (of a four-term year) - April to July. I observed her class over a 10 week period almost every working weekday, approximately 150 hours. Figure 3.1 shows a picture of Jean's classroom at Athena.

Sarah-Jane who taught at Minerva was in her 15th year of teaching when I contacted her for the research. She had taught in multiple schools in primary and middle school and as a mentor teacher abroad. She had done STEAM for a little more than one year at Minerva. Like Jean, she received no formal or informal training, professional development, or qualification in technology education. She said that she was self-taught in technology and read books and spoke to teachers on Facebook groups such as "Primary teachers of NZ" and "STEM teachers". Sarah-Jane had agreed to work for two units of audio-recording with me in the third term. However, due to some personal unforeseen circumstances, she was available only for one unit in the third term, from July-September and I was unable to do the final interview with her. She was not in school through the fourth term and data collection could not extend to the next year as Year 6 students move on to an intermediate school for Year 7. However, I had observed an earlier unit to familiarise myself with the classroom in the first term (February-March) and had

Figure 3.2
Classroom at Minerva

observation notes from that unit. In all, I observed Sarah-Jane's class for nine lessons, approximately 25 hours. Figure 3.2 shows a picture of Sarah-Jane's class at Minerva.

3.3.4 The students

In Jean's class, there were 26 students - 13 girls and 13 boys. Her class was Year 5 and Year 6 combined in a single classroom. The students were 10-11 years old. The ethnic makeup of the class is shown in Table 3.1. Of the 26 students, four parents did not give consent to be part of the research and hence their data is not included in the study. Nine parents did not give consent to use their children's photos in the research study. Although the parents consented to use photographs, of the remaining 15 students, four students did not consent to being photographed. The wishes of the students and parents are respected in this thesis and the photographs have not been used in presenting the evidence. Based on the NZC, the expected level of achievement for this age group is Level 3 (Ministry of Education, 2018a). Of the 21 students who consented in the class and whose data are available, based on their term-end reports, two students read below Level 3, 43% writing scores were below Level 3 and 29% of students had scores in Maths below Level 3.

At Minerva, there were 30 students in the class - 12 boys and 18 girls. This was a Year

6 class where the students were around 11 years old. The ethnic makeup of the class is shown in Table 3.1. Of the 30 students, 18 parents gave consent to participate in the research. Of the 18 parents, three did not consent for their children's photograph to be used in the research, and one student did not consent for their photograph to be taken. Reading, writing, and maths scores were not available for this classroom.

Table 3.1
Ethnicities of the students in Athena and Minerva

Ethnicities	Athena	Minerva
NZ European	15	7
NZ Maori	3	11
Asian	6	3
Pacific islands	1	4
Others	1	5

The students and their work will be discussed in detail in the relevant Findings section. All students (who consented) were given a pseudonym reflecting their ethnicity. The next section will detail the methods of data collection.

3.4 Methods

There are numerous methods to generate data and the choice of methods is dictated by research design, the research questions, and the paradigm of the research. As this study aims to develop the QFT-P and answer research questions related to formative assessment conducted by teachers, the main methods of data collection are classroom observations, teacher interviews, and audio and video recordings of the teacher in the classroom, photographs of student work, student generated audio/videos, and researcher notes. Each of these methods are discussed in the following sections to explain how they have been applied in this study.

3.4.1 Observations

Observation is an important method for educational research, especially for DBR. In DBR, the design process of the educational tool to use in the classroom environment offers an opportunity for the researcher to temporarily step into the classroom as a full participant or full observer (Cohen et al., 2002). Due to the introduction of the QFT-P, this study intervenes in the teacher's practices, and I interacted closely with the teacher and students. The research role can be described as a focused participant observer

(Tracy, 2013) or peripheral membership (Adler & Adler, 1994). My observations primarily involved the teacher and their conversations with the students in a naturalistic setting. However, there were some differences in observation schedules at both the schools due to the way the schools practised TE.

At Athena, due to the classrooms adopting PBL, I was unsure at first which part of the lessons to observe. I decided to observe the first two weeks to familiarise myself with the classroom and figure out a time for observation. However, after the first two weeks it was evident that some parts of TE happened all the time. Hence, I spent the whole school day in the classroom if Jean was present. I did not attend the class if Jean was not in the class. Earlier the plan amongst the senior teachers was to have five units with the same brief but different materials in one term. This was then readjusted to four units by the teachers. Accordingly, I decided to observe and record two units in detail. After the observation in the second unit for three weeks, I realised that I needed to take a break from the classroom to be able to reflect. I attended only some parts of the third unit and the fourth unit was cancelled. Hence, I ended up recording one unit at Athena but had non-audio data from one other unit.

At Minerva, Sarah-Jane practised STEAM once a week. These were the focus of my observation. I observed one STEAM unit for three weeks to familiarise myself with the classroom in term 1. Based on Sarah-Jane and my convenience, I observed and recorded one unit of STEAM unit in Term 3 after my observations at Athena were complete. Hence, I had one unit with full audio recording and another unit with detailed researcher notes and photographs. I kept notes through all the lessons and recorded my impressions after the class was over.

While my role as a peripheral observer meant that I was supposed to be only observing, it was impossible not to help in the classroom. I regularly checked the maths work in Jean's class during breaks to not affect my observation but also be able to offer some help to the teacher. I also offered to do administrative tasks if the teacher needed help. I photocopied documents or helped students with drilling holes in the plastic bottle or helped clean up the classroom. I took care to help during times where there was no technology lesson going on and I ensured that the teacher's recorder was on. In Sarah-Jane's class, I mainly observed the lessons.

Due to my hours of involvement in the classroom, Jean got used to my presence, but I felt that Sarah-Jane remained slightly uncomfortable until the end. She checked her language multiple times and commented to me that she asked certain questions or made comments about TE because I was present. The presence of the researcher obligated the teachers to use QFT-P more often. In both the classrooms, students remained uncomfortable if I placed an audio recorder next to them. Participants who are observed often change their behaviour and answer based on expected answers and not what they truly feel. Referred to as faking and observer effect/Hawthorne effect (Adler & Adler, 1994), it is a common drawback of observations. Many researchers have mentioned that teachers often forgot the presence of the researcher or forgot about the recorders (Fox-Turnbull, 2013; Hill, 2009). However, in my case this did not turn out to be true.

The total observation hours at both schools were around 175 hours. The impact of length of observation of this study on the findings is not within the scope of this research. However, it is likely that the increased familiarity with the routines of the classroom at Athena and more familiarity with the participants through the length of involvement had an impact on the data obtained, the analysis process, and my conclusions.

3.4.2 Interviews

Qualitative interview is the most common method employed in social sciences (Brinkmann & Kvale, 2018). Interviews are especially useful when looking for information that cannot be directly observed or measured (Denzin & Lincoln, 2018). In this study, interviews were used to understand the teachers' experience of using the framework and teachers' experience of teaching technology. Teacher experiences and knowledge cannot be directly observed or measured and hence, interviews are the most appropriate method to collect this information.

The different types of interviews range on a scale from structured to unstructured interviews (Cohen et al., 2002). Structured interviews are used, generally, when data is compared across large samples (Tracy, 2013) or the exact information sought is known (Cohen et al., 2002) and unstructured interviews have few questions (Cohen et al., 2002; Tracy, 2013). As Denzin and Lincoln (2018) mention in their handbook on qualitative research, no interview can be completely structured or completely unstructured. Most interviews lie between the two extremes - and are semi-structured to a certain degree. In semi-structured interviews, the participants are given an area to talk about and the conversation is guided by the researcher using prompts and following lines of inquiry as they emerge towards the insights that are sought. As the purpose of interview in this study is highly specific to the technology education and experiences of using the QFT-P, semi-structured interviews were the most appropriate type of interview method for this study.

The teachers were interviewed multiple times during the research. Both teachers were interviewed before start of observation in the classroom. The questions in the initial interview related to philosophy of teaching, technology education, perspectives on QFT-P, etc. Detailed question guide is attached in Appendix B. An additional interview with the teachers familiarized them with the QFT-P and gave an opportunity for the teachers to ask any clarification questions about the research. Interviews were conducted after classroom observations mainly centred around the teachers' experience of using the framework or suggested changes to the format of the framework. Since Jean's class was observed daily, the interviews were conducted weekly during breaks or after school. With Sarah-Jane, the interviews were conducted after every lesson observation. The final interview with Jean was centred around experiences of teaching PBL as well as the pressures, barriers encountered through the unit on teaching technology as well as using the QFT-P. A final interview could not be conducted with Sarah-Jane due to her personal reasons. Table 3.2 offers a summary of the teachers along with the topics of the interviews.

Table 3.2
Summary of interviews of the two teachers

	Jean	Sarah-Jane
Initial interview (1 hour)	Available	Available
Interview to introduce QFT-P (1 hour)	Available	Available
Classroom interviews (5-15 minutes)	Four interviews available (15 minutes)	Five interviews available (5-10 minutes)
Final interview (1 hour)	Available	Not available

3.4.3 Audio and video recording

In both the schools, both teachers wore an audio recorder to record everything they said in the classroom during the times that were relevant to TE. I recorded all the interviews. I would also periodically record some group conversations or ask some students questions and with the students' permission recorded these as well. As the audio recorder was digital, time and date of every recording was available in the audio file that I periodically downloaded to my work computer.

I seldom video-recorded the classroom at Athena - manoeuvring the video-camera across the classroom drew too much attention. At Minerva, I tried harder to video-record -

however, the students moved around a lot and lot of the video is of empty classroom. During the analysis process, the video-recordings were only used for finding any missing information like which student was the teacher talking to. Students recorded themselves as part of reflection on their technology learning - I used these videos from consented students, as data.

3.4.4 Documents

Documents make ephemeral objects and experiences, permanent (Denzin & Lincoln, 2018). Photographs were one of the main documents collected in this study. Photographs are one of the most important tools to capture and store the impressions of a complex environment like that of a classroom. Student work was photographed extensively to capture what students were working on in the classroom. Hence, students' 2D drawings, technological outcomes, writing plans and final advertising posters were photographed for analysis. Besides the photographs, student blogs, student generated blogs and Google slides were downloaded from school online system with permission.

To provide triangulation, anything written on the white board, any images shared with students, anything pinned on the classroom pushpin boards was photographed. Field notes were taken through the whole of each lesson. A further researcher journal recorded difficulties, ideas that arose through the research process and notes on ongoing analysis in line with the recommendations by Kirk et al. (1986). These researcher documents were analysed as well. As the data collected are vast and varied, the next section summarises all the collected data.

3.4.5 Summary of data collection

The amount of data from the two schools are in varied formats - photographs, audios, videos, and second-hand observation notes. This section will summarise all the data collected and identify those that will be used for analysis for both schools.

Data collection at Athena

I observed two full units at Athena, cardboard and plastic, and one partial unit, fabric. I observed and made notes in plastic unit but did not do any audio or video recording. I have photographs of student work and the teaching resources from this unit. In the cardboard unit, Jean wore an audio recorder for every lesson. I attended six out of 12 days of the fabric unit and have audio recordings, student reflection videos, and photographs. Table 3.3 details out the data collected in each unit at Athena.

Table 3.3
Data collected at Athena

Type of data	What was collected
Interviews	Seven interviews
Observation	Observation notes for ten weeks over three units
Documents	Photographs of student work from all students, Photographs of all teaching resources – on whiteboard, pin-board, any hand-outs
Audio recordings	Teacher recording in every lesson for one unit, Student conversation audios (limited)
Video recordings	Student reflection videos, Limited videos of the classroom

Data collection at Minerva

I observed two units at Minerva. The units were *Hinaki* (eel-trap) and water-filter. I observed and made notes in the *Hinaki* unit but have no photographs since I did not have parent consent by then. The teacher wore a recorder for the water-filter unit, and I took photographs of student work, video recorded of the classroom, and took notes. Table 3.4 lists all the data collected at Minerva.

As the data is complete with audio recordings for one unit in both schools, the unit that is audio-recorded was considered for analysis for the research questions. Partial data from other units were used for explaining the development of the QFT-P and used sparingly in the rest of the thesis. Before explaining the analysis, the different iteration rounds of DBR are described below.

Table 3.4
Data collected at Minerva

Type of data	What was collected
Interviews	Seven interviews
Observation	Observation notes of nine lessons
Documents	Photographs of student work from all students for one unit, Photographs of all teaching resources – on whiteboard, pin-board, any hand-outs, Google slides prepared by students (weekly) for one unit
Audio recordings	Teacher recording in every lesson for one unit, Student conversation audios (limited)
Video recordings	Student reflection videos for one unit, Videos of the classroom for one unit

3.5 Iteration rounds

There were five rounds of iterations in this DBR. For the first iteration that occurred prior to research on-site at the school, I modified and extended the original TOCF to align with the NZC and from this point the modified TOCF is referred to as QFT-P to distinguish it from the original. At this stage, both teachers were introduced to the QFT-P. Due to availability and convenience of the participants and researcher, I decided to collect data at Athena first.

The QFT-P was presented to Jean, the teacher at Athena as nine coloured sheets before the start of Term 2 so that she could use it for planning her technology unit as per recommendation from the last study that used the TOCF (Fox-Turnbull, 2018). Jean had the QFT-P sheet format for planning the unit. She used the QFT-P through two weeks of the unit and we discussed how she felt using it. Based on her feedback, I decided to modify the QFT-P to a card format. However, preparing this format was going to take a while and I presented a temporary version of QFT-P to Jean to use meanwhile. After two weeks with the temporary QFT-P, I had finished modifying the QFT-P to small cards and I presented this to Jean. Jean used this version for four weeks. By this time, the term was over at Athena, and I presented the cards to Sarah-Jane at Minerva before she started the unit. Based on Sarah-Jane's feedback, I provided limited selection of cards of the QFT-P based on her feedback during the unit and added more cards when she was comfortable.

Table 3.5
Round of iterations and data used for analysis

Rounds of iteration	Version	School, unit
Round 1	TOCF to QFT-P	-
Round 2	QFT-P in sheets	Athena, Plastic unit
Round 3	Temporary version of QFT-P	Athena, Cardboard unit
Round 4	QFT-P in card version	Athena, Partially cardboard unit and Fabric unit
Round 5	QFT-P cards – offered few at a time	Minerva, Water-filter unit

Table 3.5 explains the round of iterations and their correspondence with the data collection units. There were five rounds of iteration and each round included teacher feedback and a modification to the framework. The first round was modification of the TOCF into a sheet version of QFT-P. The second round was Jean using the sheet version of QFT-P. The third round was Jean using a temporary version and the fourth round was Jean using

a card version of the QFT-P. Sarah-Jane using some of the cards of the QFT-P at a time was the fifth and final round of iteration.

3.6 Analysis

The methods of analysis are dependent on the research questions. For the experience of the teachers using the QFT-P and the various iterations, teacher voice was the most important and hence, the data was mainly from teacher interviews, photographs of the iterations and the researcher notes on the different iterations. For analysing the use of QFT-P as formative assessment, the teacher audios from the classroom and the observation notes were the main sources of data and the analysis was triangulated from photographs of the classroom learning resources, researcher notes, and the teacher interviews. For analysing the influence of the teacher-student conversations on student learning, the classroom audios and photographs and videos of the student work were the main sources of data along with triangulation from the photographs of learning resources, researcher notes, and observation notes. Table 3.6 sums up the sources of data for different research areas. Data preparation for analysis is described next.

Table 3.6
Type of data for each research area

Purpose of analysis	Main data used
Using QFT-P as formative assessment	Teacher audios, observation notes
Experience of using QFT-P	Teacher interviews
Dialogue in IFA	Photographs of student work, student reflections

3.6.1 Data preparation

DBR is an iterative process where the teacher's opinions and commentary decide direction of the iterations. In this study, there were five rounds of iterations. The teachers were interviewed before and after every cycle and the transcriptions of these interviews were the main data sources for the analysis for this part of the study. Besides teacher interviews, the researcher notes form the other source of data.

The interview data was imported into NVivo and read multiple times for familiarisation. NVivo was used to, both, manage and analyse the vast amount of data collected for this study. Use of NVivo can also improve the trustworthiness of the research as it can allow for data to be consistently managed, coded, and retrieved (Kelle &

Laurie, 1995). Interviews were then coded. The main codes for the interview transcriptions related to teacher beliefs about teaching, technology, teacher's role in the classroom and the teacher experience with technology education. For their feedback on the QFT-P, some examples of codes were feedback, experience with QFT-P, and barriers. For the analysis, it was necessary to first prepare the appropriate data from the vast number of photographs, timetables, researcher and observation notes, and teaching resources. As a first step, I prepared detailed notes on how the units of technology progressed at Athena and Minerva. Sample of these notes are shown in Appendix F. These detailed notes included the timetable at the schools and my first impressions of the school, teachers, students and what happened in the classroom. These notes were created right after the research at Athena was completed. After completing the notes, I focused on arranging the data, transcribing the data, and doing other administrative tasks related to the research process so that I had time for reflection.

The analysis stage took more time than I anticipated and the extra time proved beneficial to the process. Due to the global COVID-19 crisis and due to personal health issues, I ended up slowing down the analysis of the data for several months. On approaching the data after many months, I proceeded to re-familiarise myself with the data by reading and re-reading researcher and observation notes, and the deliberation notes. The step-back helped me see a path forward with the analysis. The next step of data preparation was to prepare a detailed timeline and timetable of the different changes to QFT-P. The interview data, deliberation notes, researcher notes, and observation notes from the classroom were the main data sources for preparing this part of data. Classroom audios, videos and photographs were used to triangulate the data. The codes from the interviews that related to the QFT-P were separated through a query in NVivo and read multiple times in preparation for writing the Findings chapter. At this point, an anlytical framework was needed to analyse the prepared document further.

3.6.2 Analytical framework

This study, typical to any DBR, focuses on the insights from the iterations and modifications of the learning tool. The DBR's focus was to develop the QFT-P to a format that primary, technology teachers could use as a formative assessment tool. Since the output at each stage of iteration was a concrete object, it could be thought of as a technological outcome. A technological outcome is evaluated based on if it fulfils a need or demand of the consumer and meets a set of attributes (Ministry of Education, 2018b). A similar direction for evaluation of the QFT-P is adopted in this study. The analytical framework is, thus, based on the evaluation of technological outcome. The evaluation of the research echoes the context of the research. The research question about the ways in which the QFT-P could be used as formative assessment tool in the primary, technology classroom is answered through the analytical framework.

A technology is successful when it meets the requirements of its consumers and stakeholders. In this case, the different stakeholders are the teachers, principals, students, and parents of the students. The main consumer are the teachers. The teacher's inputs determined the direction of development of QFT-P through the process of DBR. The needs of the teachers, principals, and students helped to write a list of attributes of the technological outcome. The different attributes of QFT-P are discussed below.

- The most critical aspect of any process or tool or any practice in a classroom is to have a positive impact on the student learning - QFT-P should allow for a positive impact on student learning.

- Based on the review of the existing literature on dialogue and its benefits, it is intended that QFT-P use results in a deep and rich dialogue between the teacher and the student(s).

- Based on data from the study conducted by Fox-Turnbull (2018), QFT-P could aid teachers to develop their technology curriculum content knowledge and associated vocabulary

- The teacher is busy, and introduction of new tools could be source of additional tension. The research aims to focus on increasing the user-friendliness of the QFT-P so that teachers do not need to spend additional time in learning to use it.

- Using QFT-P should not increase the workload of the teacher.

- Any tool used in the classroom should be flexible - QFT-P should grow as the teacher's needs grow and change and be compatible with other tools/ processes in the classroom. It should not require major changes to the existing routines of the classroom.

- For any technology, an important attribute is the cost - the QFT-P should have very low cost to the user. The cost of any technology includes the development costs, distribution costs, license costs, training costs and maintenance costs.

The above attributes were determined based on my understanding of a technology classroom, a primary classroom, and general technology evaluation criteria. The data were analysed based on the presence or absence of evidence for each of the attributes. The next two sections provide details about the analysis for using QFT-P as formative assessment and for student learning.

3.6.3 Analysis of data for purpose and attributes

The data was analysed to find evidence of use of QFT-P as formative assessment tool by the teachers and for the various attributes of the QFT-P outlined in the previous section. The first step for the analysis was to familiarise with the data through listening of the audios from the classroom and making notes in Google docs about each audio. The notes focused on summarising the audio and had information on the what the teacher was doing at different times in the lesson. If any student voices were heard and recognised, notes included information about what the student said. The notes had time indicators of when any question from the QFT-P was asked. The audio bits with the QFT-P questions were heard multiple times to summarise the conversation. Any other question not from the QFT-P asked by the teacher was noted without time stamp or transcription. Researcher notes and videos from the classroom were used to complete the notes in case it was not clear which student was speaking in the audio or information was needed on the context of the conversation. Any dialogue that was recognised as important, was transcribed in full.

Once the questions from the QFT-P were isolated from all audios, all notes regarding the conversation between teacher and student(s) were transferred to an excel sheet (an example is presented in the Appendix I). After the excel sheet was made, the detailed notes from the whole audio were perused again and it was noted that there were conversations between the teacher and the student(s) that did not originate with a QFT-P question. These questions were categorised, and a decision was made to either incorporate them in the analysis. The decision about these questions is discussed in Table 3.7. The excel sheet was modified by deleting the non-QFT-P questions.

The class timetable and lesson objectives for each lesson was prepared in a separate excel sheet (Appendix G) for triangulation. Some basic description statistics related to the QFT-P were calculated such as the number of instances of questions, the level of the questions when compared against the NZC, the strands from which the questions were asked and their percentages, and number of questions asked by each teacher. The excel sheets were read multiple times to become familiar with the data for analysis purpose. The conversations between the teacher and student were the focus at this point. The conversations were analysed from the perspective of the definition of formative assessment used in the study. Did the teacher show evidence of understanding the student learning and extending the student learning? If yes, the conversations were IFA, and the pattern of the conversation was noted to compare with existing model of IFA from literature. Evidence for presence or absence of attributes had to be analysed from the data. Aspects of thematic approach was used to look for the evidence. In thematic

Table 3.7

Questions not originating from the QFT-P and their inclusion/exclusion in the analysis

Question type	Example	Rationale for inclusion or exclusion in analysis
Similar to the questions in the QFT-P In this category teachers' questions were not directly from the framework but were similar to questions/combination of questions in the framework.	"Do you think the customer would like this feature?" "What are you doing now?"	Included. Although the QFT-P does not have these exact questions, they could be considered part of the framework due to their similarity with it and will be added to the updated version of the QFT-P at the appropriate level and under the relevant behaviour.
Generic Questions The second category of questions were generic questions that lead to conversations but were not specific to technology and could be applicable to other learning areas as well.	"Is this creative?", "What do you wonder about?", "What questions do you have now?", "What are your goals for this lesson?", "What did you notice?", "What question are you looking to answer (doing online research)?", "Why?", "How?"	Excluded. During design of QFT-P, it was decided to make the framework technology specific and generic questions were not used. Teachers encounter generic questions in multiple books, PD sessions or in conversation with teachers. The aim of QFT-P was to provide technology specific questions which were not common in teachers' lexicon.
Context-based questions	"Why is this hard to measure?", "How are you going to connect this arm?", "Why have you cut this bottle?", "Are those wheels going to turn?".	Excluded. These questions were highly specific to the products being made and have not been included in the analysis since they are unlikely to be repeated by any practitioner in the exact form.
Meta-cognitive questions Questions to make one think about what they are doing	"What is market research?", "What if you want to include a feature that is against what the customer wants?", "What does it mean when you test something?"	Excluded. These questions are not included in analysis since these questions do not appear in the IoP or technology curriculum.

approach, the data is coded and themes are identified from the codes (V. Clarke & Braun, 2017). The thematic approach works for both inductive and deductive methods (V. Clarke & Braun, 2017). The aspect of thematic approach used in this study was to look for known themes from the data akin to deductive thematic analysis. The attribute on student learning required different data source and hence, was analysed differently.

Student reflection videos were transcribed in NVivo as video transcriptions proved easier in NVivo. As the videos were transcribed, they were coded with the student's name and date of the reflection video. They were then coded with further codes according to if the reply related to their product or to the process of making or to the changes they made. Once the student reflection videos were coded, student "blogs" which were available in PDF format were also uploaded and coded in NVivo.

3.6.4 Analysis of data for student learning

For analysing student learning, one of the main data sources were the photographs of the student work. The student work in Athena had 2D drawings made by the students, the work in the "inquiry book" which included their rough drafts and brainstorms and the work in the "writing book" that contained the drafts of their writing plans, their final technological outcome, their final advertising posters, and their uploaded blogs and video reflections. The student work at Minerva included their rough plans for the water-filter, the two prototypes of the water filters, their video reflections, and the google slides the students prepared in groups. The student work at Athena is available for individual students while the student work at Minerva is available for student groups. The vast number of photographs (approximately 500 in number) were uploaded to NVivo, and the photographs were coded with the student's name, school's name, and the technology unit. Identifying codes were then allotted to all the photographs. Photographs are not analysed and coded in detail - information needed from photographs was extracted as needed.

The guiding literature on preparing the students work for analysis was based on Alton-Lee and Nuthall's generative methodology (Alton-Lee & Nuthall, 1992). Alton-Lee created the concept of "item files" (Alton-Lee, 1984). Item files are a chronological arrangement of the student's experience in the classroom with a specific concept they either learnt or did not learn in the classroom. The modified item-files created in this study were not created for every concept in technology the student encountered but for the technology unit as a whole. Item-files were created for every student group - 12 groups in Athena and four groups in Minerva. NVivo project had all the work of the students except for their dialogue with the teacher which was available in a separate excel sheet. Two additional columns were added in the excel sheet to indicate what was the teacher's expectation after the conversation and what the student did.

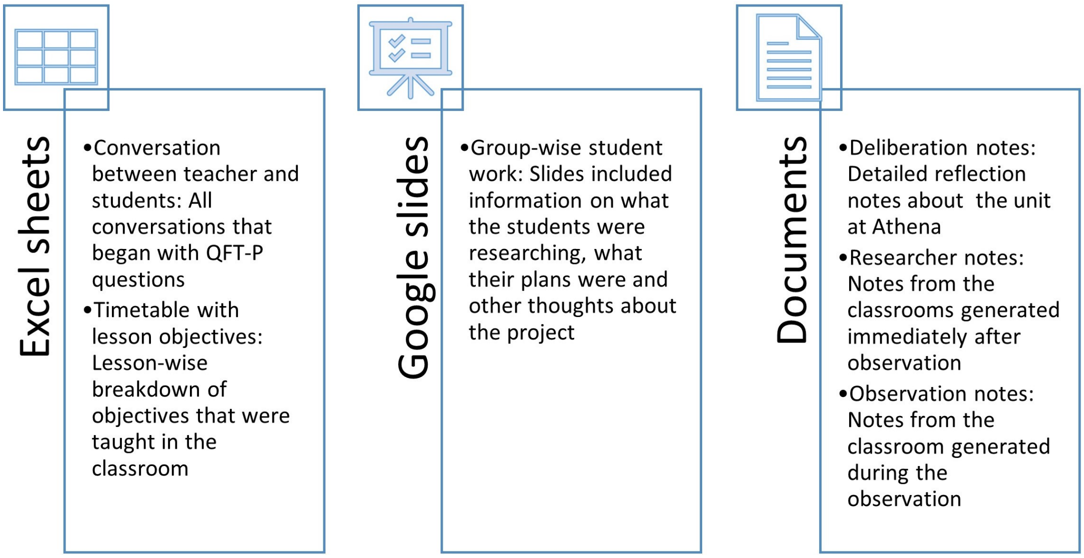
The excel sheet made for the lesson-wise breakdown (Appendix I) was read again. The lesson objectives were compared with the NZ technology curriculum and IoP and the levels, strand, AOs were noted in the same excel sheet. The student indicators from IoP were read multiple time for each lesson objective and the relevant student work was examined and matched for presence or absence of the indicators. This part of analysis resulted in evidence for student learning against the NZ technology curriculum. However, it was noted that students' item-files indicated meeting objectives that were part of the teacher's priority objectives for the classroom. Teacher interviews were read again and the teacher's priority objectives for each class were noted. Student work was then examined to find evidence of presence or absence of meeting the teacher's priority objectives.

To find out additional insights, it was necessary to look at the data in a different way. One way of looking at the data was to look at it from the students' perspective. To visualise the data for a student in a single space along with the timeline, a google slide was made for each student group for the technology unit under analysis. A sample of the slide is shown in Appendix H. The google slide had the entire timeline for the unit in a single sheet for the three weeks along with the photographs of the student output for each other. The conversations students had with the teacher was marked on the same sheet to look for patterns between the frequency of teacher-student conversation and student output. The google slides, thus, represented these modified item-files - a record of the complete picture of the student(s)' experience in the classroom for the technology education expressed through their output and the conversation with teachers. Once the modified item-files were created, a picture emerged of every specific student group's learning experience in the technology unit. The main analysis focus for this part of the data was to be what in the dialogue helped student progress on their technology learning. By becoming familiar with the student group's dialogue with the teacher, patterns emerged on how the teacher-student conversation influenced what the student did next - and the effect on the final technological outcome. Figure 3.3 shows the various documents prepared for analysis.

3.7 Trustworthiness

The criteria given by Lincoln and Guba (1985) for qualitative researchers is to consider how a researcher can show that their study is worthwhile. This boils down to the issue of trustworthiness, which in turn encompasses five criteria: credibility, dependability, confirmability, transferability, and authenticity (Elo et al., 2014; Y. Zhang & Wildemuth, 2016).

Figure 3.3
Documents prepared for analysis



For credibility, the right methods should be chosen to answer the research questions. This study aimed to collect multiple types of data that will offered triangulation and a richer picture of the classroom. Triangulation enhanced credibility (Marshall & Rossman, 2014) and offered depth to the data. Dependability is demonstrated by adequate background information and eventually reporting the background and all relevant non-identifying information of the participants so that the reader may judge for themselves. This links to the requirements by pragmatism as well. Accordingly, all background information has been reported in the thesis. Warranted assertions at the conclusion of the study provided with enough background can encourage practitioners and researchers alike to consider the applicability of the assertions to their situations. Use of participant voices in reporting of the findings add to the confirmability and authenticity of the study. Limitations and negative cases are reported as well. Member checking of the interviews and recording of the interviews and classroom added to the authenticity and confirmability of the study. There are limitations to the authenticity as this is a doctoral study and theme generation from data was not done with multiple researchers. However, the presence of the supervisory team who listened to the emerging reflections from the data analysis phase mitigated some of this stated limitation.

3.8 Ethics

The ethics for this study has been approved under FEDU082/18 on November 8, 2018 by the Department of Education Ethics committee at University of Waikato. The ethics approval is attached in Appendix C. The key concerns of ethics for this study are summarised below.

3.8.1 Informed consent

All Principals, teachers, students, and their parents were informed about the research through an information letter and their signed consent was obtained (see Appendix Q). With teachers and students, a talk was organized to explain the research process and their role in it. Besides the forms, the talk clearly mentioned about right to consent, right to withdraw consent and contact details of chief supervisor in case of any personal conflicts. This information was also sent to the parents through information letters. Although the students' consent was not needed as they were below 18 years old, their consent was taken and respected in this study in line with suggestion by Morrow and Richards (1996). The consent forms for the parents and students offered them a choice for them to consent to use their photographs in the dissemination of the research.

3.8.2 Anonymity/ Confidentiality

Every effort was made to ensure anonymity. The schools are given fictional names. All participants are referred to using pseudonyms. Care is taken and will continue to be taken when describing schools and teachers to ensure they are not easily recognisable. Anonymity cannot be guaranteed, however, and the participants have been informed about the possibility of losing anonymity. No third party was given access to consent forms or information regarding the schools or teachers.

Confidentiality has been maintained through anonymising the transcripts and ensuring that no one except the supervisory team has access to the raw data. No third party was involved in the transcription of the video or audio recordings. There are no photographs of students used in the thesis. Photographs and video, however, could be used in the dissemination of the study and this was clearly mentioned in the information letters and consent forms. Parents and students were given the option of not allowing students' images to be used during the dissemination process. In accordance with the parents and students' preferred options, those images were not used in this thesis, and it will continue to not be used.

3.8.3 Potential harm to participants

No potential harm was anticipated in this research. All students and parents were clearly informed about the parameters and goals of the research and their right to withdraw without any repercussions. Even if consent was obtained and any student showed visible discomfort directly attributable to the research, the student was given an option to withdraw immediately. Sometimes this meant that audio recorders were stopped, or interviews halted.

Power differentials can cause direct and indirect harm to the participants. The students were clearly informed by the teachers that I was conducting research and what my role in the classroom would be. I helped the teachers in the classroom and rarely worked directly with the students. When I helped out the students at the teachers' directive, I tried to work collaboratively and worked as extra pair of hands without offering any suggestions or directions.

The other way to cause harm could be indirect – for example loss of time for learning. The research plan included the time the teachers needed to understand and plan using the QFT-P outside of classroom time so that student learning was not affected. Support was provided at every stage of planning and execution process to ensure that the teacher was able to meet the learning goals for the unit. The framework was designed for use in the classroom during normal classroom procedures. There was no visible, perceived or claimed loss of time for learning due to the use of the QFT-P.

3.8.4 Participants right to decline and withdraw data

Both teachers were informed of their right to decline and withdraw data. Both teachers were informed that it was not possible to request any changes or withdrawal after one month of the final member checking. They did not send any such request. For the students, they were informed that they could withdraw at any time during the study until a month after completing of the data collection process at the schools. No requests were made for withdrawal of data by any student or parent.

3.8.5 Arrangements for participants to receive information

All the teachers were provided transcripts of their interviews for member checking. The teachers had the right to comment on the transcripts and withdraw, amend, or clarify anything within two weeks of receiving the transcripts. However, neither teacher gave any comments on the transcripts.

At the end of the research, the teachers will be provided the links to the research report and any other journal articles from the research until that date. An easy-to-understand multimedia presentation will be provided to the teachers and the principal.

3.9 Chapter summary

The methodology chapter has offered a detailed overview of my actions in this research study and the reasoning behind the choices that shaped research design. The conceptual lens of Deweyan Pragmatism influenced the research questions and the values inherent in Deweyan Pragmatism led to the methodology of DBR. DBR offers a critical voice to the participants in this research and the voice of the teachers determined the direction of the development of the QFT-P. The methods of data collection were through extensive classroom observations, interviews, photographs capturing student work and teaching resources, audio recording of the teachers, and video recording the classroom. The length of classroom observations was approximately 175 hours over two terms and more than 500 photographs, 14 interviews lasting six and half hours, approximately 35 hours of audio recording were the main sources of data for analysis.

This chapter also introduced the two schools – Athena and Minerva and the two teacher participants – Jean and Sarah-Jane who taught 56 students between 10-11 years old. Jean and Sarah-Jane determined the direction of development of the QFT-P through five rounds of iterations. Whether the QFT-P can prove to be a useful tool for IFA is determined by the analytical framework of the study modelled on technology evaluation process. Hence, analysis focused on looking for evidence for the use of QFT-P as formative assessment tool and fulfilling seven attributes. The six attributes – deep and rich dialogue, teachers learning about technology, no time loss for the teacher and students, user-friendliness, flexibility, and cost – are analysed deductively from the data. The attribute of positive impact on student learning was analysed by arranging the student data as modified item-files and using aspects of thematic analysis to look for presence/absence of student learning.

During the research process, the principle of doing no harm was followed through asking for informed consent and informing the participants of their right to withdraw. Genuine attempt to maintain anonymity and confidentiality has been made throughout the study. Through the research process, steps were taken to ensure trustworthiness of this research through using multiple sources for triangulation, offering participants a chance to member check their interviews, providing background non-identifying information for providing a context for the study. The next chapter on findings will include the voices of the participants with context so that the reader may also judge the trustworthiness for themselves.

Chapter 4

Development of QFT-P

> Between those two termini of observation, we find the more distinctively mental aspects of the entire thought-cycle: (i) inference, the suggestion of an explanation or solution; and (ii) reasoning, the development of the bearings and implications of the suggestion (Dewey, 2011, p. 78).

Findings for this study are presented in three chapters. This chapter discusses the development process of QFT-P and the teacher's feedback that guided the development. The next chapter, Chapter 5, titled "Use of QFT-P in the classroom" presents the findings from analysis of the data relating to the its use as formative assessment and the attributes of the QFT-P except for student learning which is presented in the last findings chapter, Chapter 6, titled "Student learning". In this chapter, we start with discussing the structure of the units at Athena and Minerva and a look at typical days at both schools so that a clear picture of the classroom can be envisaged before we discuss the five rounds of iteration of the development of QFT-P.

4.1 Structure of the units

In this section an outline of the technology units and a typical day at both the schools is provided to situate and interpret the evidence presented later in the chapter. As mentioned in the methods chapter, two units were observed and one unit from each of the school was used for analysis. Athena school was following integrated PBL approach to inquiry learning and their technology unit spanned most of a full working day. Minerva school was teaching TE through integrated STEAM and the technology unit was enacted for half a day once a week. At Athena, the units were plastic (observed only) and cardboard (observed and audio/video recorded). At Minerva, the units were *Hinaki* (eel traps) (observed only) and water-filter (observed and audio/video recorded).

Figure 4.1
The design brief from Athena for cardboard unit

Structure of unit at Athena

At Athena, the senior primary classes taught all the learning areas using integrated PBL approach. For the term when I observed, the senior class teachers had decided to run four units. In each unit, they planned to do the exact same lesson structure and give the same design brief except for changing the material. For the first unit, the teachers had decided to use plastic, the second unit was cardboard, the third unit was fabric, and the fourth unit was to be using food. Each unit was to last two weeks. However, during execution, the first unit was two weeks and the second and third units were three weeks each. There was no fourth unit.

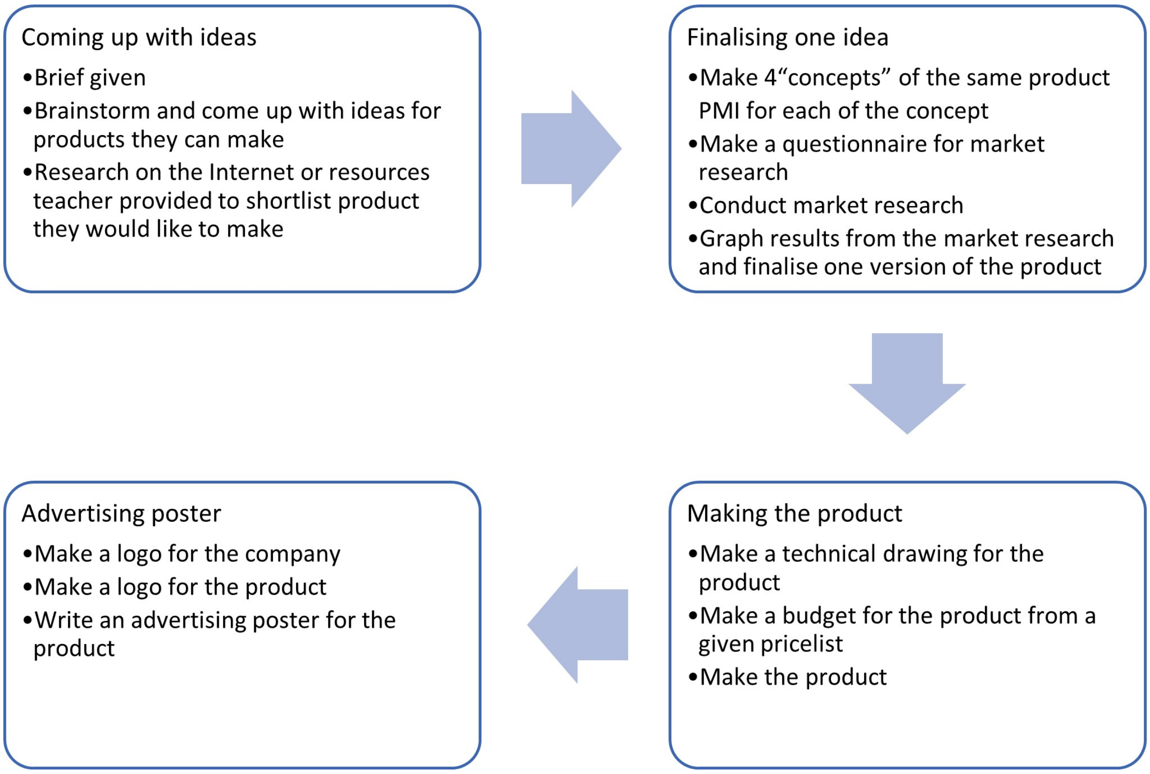
The design brief to the students was to create products for selling in a market and the customers were to be students from other senior primary classes. Initially, the teachers discussed wanting to hold a final market day and sell the products for fund raising. But this plan was dropped. Instead, at the end of each unit, there was a market day where the senior primary classes went to each class and “bought” the products. To buy a product, each student was given a notional NZD 20. They had to record in a sheet which products they bought, and they could not “buy” products for more than NZD 20. The students were also encouraged to give the sellers feedback on their products.

In the cardboard unit used for analysis, students were given the brief: Design and build a product to sell at a market, using recycled cardboard (see Figure 4.1). For the cardboard unit that lasted three weeks, students were to come up with multiple ideas and finalise one idea in the first week, make the technological outcome in the second week, and make the logo and advertising poster in the third week. At the end of the third week, students had the market day. Figure 4.2 shows the three-week lessons in detail.

The students spent nine to eleven hours per week working through PBL. The other times, students were in fitness, Maori lessons, or library. In Week 1 and 2, Jean organised small reading groups with reading related to the design process. Jean also worked

Figure 4.2

The three weeks taught at Athena in detail



with different groups on helping them calculate budgets. Group time lasted around 20 minutes and Jean would walk around the class observing and talking to the students for 10-15 minutes before working with another group.

Students were asked to bring used waste cardboard from home. Other products like glue sticks, paints, and strings were provided by the school. The students could bring other decorating material from their homes if they wished.

Structure of unit at Minerva

At Minerva, Sarah-Jane conducted STEAM lessons, once a week for half a day. The two units I observed in the class were focused on technology. The brief of the first unit was to make a *Hinaki* (an eel trap) with modern materials. The brief of the second unit was to make a water filter with materials provided. The technology need for the water-filter was to be able to filter dirty water with commonly available materials during a natural disaster. The given materials were pebbles, sand, charcoal, fabric, filter wool, coffee filter, and recycled plastic bottles. At first, Sarah-Jane planned to get the students to build a water-filter and then to transfer that knowledge to make a filter for drain on the roads (Interview 2 with Sarah-Jane, lines 8-11). After the first lesson, Sarah-Jane felt the students did not have enough background knowledge to make a water-filter for drains and she felt that an online search resulted in an image of a water-filter that students would copy and not learn anything in the unit. So, she changed the structure of the unit having two rounds of making a water-filter. For the first round, she did not allow students to search anything online and to build the water-filter however they wanted. Of the seven groups, only one group got visually clear water from the water-filter they built. Sarah-Jane then asked students to research online and learn the function of all components. In the next round, the students built the water-filter again after having researched the components. In this round, all but one group got visually clear water. To close, Sarah-Jane spent two and half lessons asking students to reflect on the process of making the water-filter.

The water-filter unit took 6 weeks to complete. The structure of the lessons was broadly as follows:
Week 1 - Introduction to the brief with a video
Week 2 – Making the first prototype of a water-filter
Week 3 – Doing research on materials
Week 4 - Making the second prototype of the water-filter and one hour of reflection
Week 5, 6 - Reflection

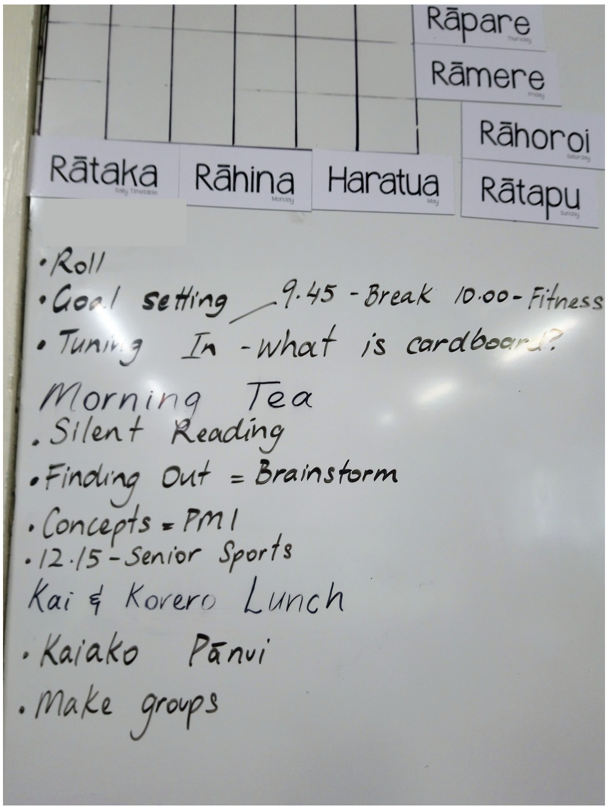
The students spent around 16 hours in this unit. Except for the recycled plastic bottles that students bought from home, Sarah-Jane bought all the materials required for making the two products. Sarah-Jane spent the unit conducting classroom discussions for the first 10-15 minutes followed by work-time where students had a specific target to complete, for example, research on the materials. During the work-time, Sarah-Jane interacted with different groups asking questions and conducting dialogue to gauge student understanding and providing additional support for students who were struggling. After the work-time elapsed, Sarah-Jane had a whole class discussion on what the students discovered before providing the target for the next work-time.

Typical day of Technology Education

At Athena, the typical day began with 'circle time' where students sat in a circle and discussed their week or conversed on a topic led by Jean. Jean took roll call during this time. Jean then conducted a Maths quiz for three minutes. Once the maths quiz was done, Jean introduced the day's objectives to the students. She normally had the entire timetable written on the board (see Figure 4.3). If the objectives needed to be introduced, Jean did that next for around 15 minutes. The students then worked on their project based on the objectives for the day.

Figure 4.3

Timetable at Athena written by Jean



At around 10AM, the students had a snack and would do physical fitness until 10:20AM. The students again worked on their project from 10:20AM until morning tea at 11:00AM. After morning tea, the students worked from 11:45-12:15PM on their projects again except on Thursdays when they went to the library. At 12:15 the students went to play sports, followed by lunch. The students came back to the class at 14:00 and were shown a short 15-minute animated video on entrepreneurship. The students then worked on their projects until 14:45. At 14:45, Jean would ask students to pack up and 'circle time' with them where they played a game. Students left at 15:00, the end of the school day. In all, students usually worked on their projects between: 9:15-10AM, 10:20-11AM, 11:45-12:15PM and 14:15-14:45. The total number of hours students worked on a typical day on their project was 2 hours and 35 minutes.

At the beginning of the day, after the students moved on to do their projects, Jean typically spent the morning slot working with specific students with learning difficulties in the classroom. After she explained the tasks of the day to these students and typically, broke down the tasks for them further, she would walk around the class and talk to the other students. She followed up repeatedly with students who had difficulties and monitored their progress.

Jean worked with groups, usually in the time slots before and after morning tea. Jean would have small group discussions on reading and maths lasting 20 minutes when most other students were working on their project. The reading was typically connected to the unit and the maths lessons were to help students to calculate the price of their product and do other related decimal addition and subtraction.

At Minerva, the typical STEAM lesson began at 11:45AM. Sarah-Jane normally introduced the goal for the day's lesson. If it was the first lesson for the unit, Sarah-Jane spent time setting up the lesson and providing the brief for around 20 minutes. After this, she asked students to work in groups on a specific task. She often gave them a fixed time to work on the task and asked all students to come back on the mat after this time. After a group discussion on the task they finished, Sarah-Jane either gave them more time if she was unsatisfied with the output or gave them the next task. The students would go away again for a fixed time. During the time students worked in groups, Sarah-Jane would circulate between the different groups and have a dialogue with the students about their learning. There was a lunch break at 13:15. Students returned from lunch at 14:00. Some weeks, Sarah-Jane would stop at this time and not do STEAM. Other weeks, students continued with their STEAM after lunch and until 14:45. During these 45 minutes, they would continue with the task for the day in their own groups while Sarah-Jane circulated to troubleshoot any issues that arose.

Having established a picture of a typical day of TE at both the schools, the following section and chapters will present further findings from the study. The next section will present the development of the questioning framework used.

4.2 Iteration rounds

The DBR development of the QFT-P is presented in this section. These rounds or iterations follow the DBR approach of developing a resource in-line with continuous feedback from the practitioner and theory. The first iteration was derived from theory. The subsequent four iterations occurred with the two participating teachers in this study. Round 2-4 happened at Athena with Jean and Round 5 with Sarah-Jane at Minerva. At the beginning of the project, the aim of the iterations was to develop the content and structure of the QFT-P based on feedback provided by teachers using it in the classroom. The sections below describe in detail the different rounds of iteration

4.2.1 Iteration round 1

Round 1 took place from January 2019-March 2019. This iteration round occurred before any classroom observation and the focus of this round was to develop a version of the TOCF (Fox-Turnbull, 2018) that aligned with NZC and to be used in this study.

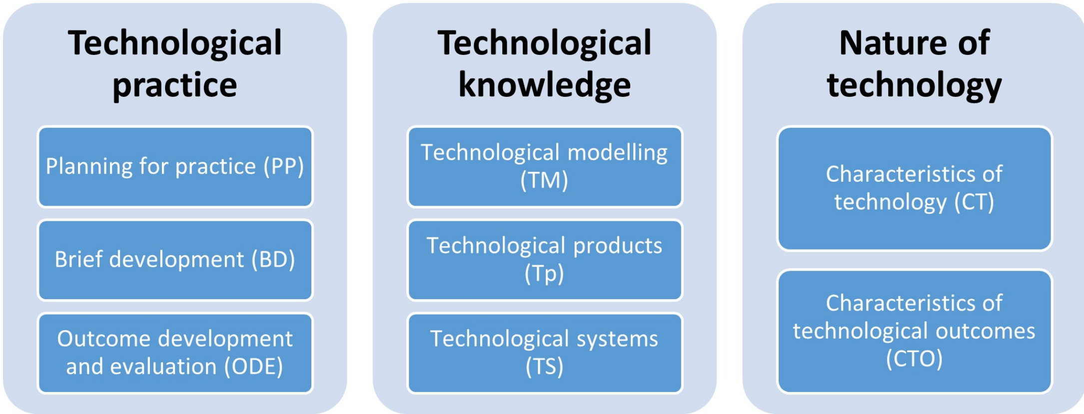
The original TOCF, as explained in Section 2.4, had observation cues and comments in addition to the questions. For this study, the focus was to look specifically at the questions that initiate the dialogue. The observation cues and comments were then removed from TOCF with intention of adding them later based on feedback from the teachers. I anticipated the need to rename the framework in this study as it became different to the original in a number of key aspects. I now referred to the modified framework as Questioning Framework for Technology - Primary (QFT-P).

The QFT-P was then only a framework of questions. The columns in the QFT-P were the behaviours that aligned with the key competencies in NZC. The five aspects that formed rows of the original TOCF were derived from multiple design and technology curricula. The focus was on NZC for this study as the plan was to work with NZ teachers. In the 2016 NMSSA survey, one of the points that emerged was that only 38% of primary teachers were aware of the IoP (Ministry of Education and NZCER, 2016). Of the teachers who knew the IoP, only 14% used it "*quite often*" or "*very often*" (ibid). I reasoned that creating a completely new resource with no connection to existing curriculum was not a good choice. It was necessary to make new resources that aligned with NZC and IoP so that teachers who were familiar with these documents could find it easier to use the QFT-P and teachers who were unfamiliar could use the QFT-P to become more familiar with the NZC. An alignment with the curriculum would familiarise the teachers with the terminologies and language in the TE curriculum. Hence, the rows in the QFT-P were derived from the strands of TE curriculum: Nature of Technology (NT), Technological Practice (TP), and Technological knowledge (TK). These three strands have the components as shown in Figure 4.4.

Once the rows and columns were known, the next step was to modify the questions to fit in with the NZC. The QFT-P was envisaged for primary, and it was necessary to modify it for a wider age range since the original TOCF was designed for elementary students. In line with the Indicators of Progression (IoP) in the NZC, it was decided to have different levels of questions corresponding to the levels of progression. Different levels ensured that teachers had flexibility to work at any level based on the students in the classroom. Considering that the target age group was ten-year-olds which corresponds to Year 6, it was planned to develop the TOCF up to the level appropriate for this age

Figure 4.4

Components and strands in the NZC



group – Level 3 (Ministry of Education, 2018a). An additional level – Level 4 was added so that teachers could see the progression for the next level and they had the option of preparing students for a higher level. After deciding the levels, the IoP and NZC was read multiple times at each level. For preparing the questions, the teacher guidance notes and student indicators from the IoP proved invaluable as the AO in the NZC can be complicated to unpack for a context. Once questions were prepared, they were checked to ensure that they were open questions that is known to promote critical thinking. Any generic questions (What are you doing now?, Can you describe this?) were eliminated. The questions were then classified based on the behaviour they could promote. The five behaviours from the original TOCF were retained. The five behaviours are Reflecting, Socialisation, Sophistication and Flexibility, Resilience, and Transference.

For an example, the component CT from the strand NT at Level 3 has the AO: "*Understand how society and environments impact on and are influenced by technology in historical and contemporary contexts and that technological knowledge is validated by successful function.*" One of the teacher guidance note for this AO is "*provide students with examples of different technologist's practice and guide them to identify how social and environmental issues could have influenced their decision making about; what should be made and why*". The indicator was "*describe how societal and/or environmental issues can influence what people decided to make*". The question that was created reading the above AO, teacher guidance note and indicator was "*If you had to worry about <u>specific environmental concern</u> (example: decomposable packaging, being vegan) how would the product design change?*" The underlined portions were italicized in the QFT-P and the teacher could substitute any relevant environmental concern based on the context. The same AO and teacher guidance notes also influenced formation of the question "*How would <u>this technology</u> look different if people buying this technology valued environment over the price?*". It is clear from this process that there could be lot of variation in questions for the same AO. These questions could be modified and changed and updated based on what the teacher needed for their context and unit. The idea was to start the teacher asking high-cognitive relevant questions and get the teacher familiar with the many ways the IoP could be used. Aligning the QFT-P with the NZC and IoP increased the number of questions.

The earlier framework had 91 questions and was created for early childhood and early primary students. The QFT-P had 252 questions and could now be used for students from ages 5-12 (Year 1 to Year 6). This was considered a good solution as the QFT-P could now be used by the teacher year-after-year with the same students or different groups of students. I recognised that 252 was too many questions and if put in the earlier format, it would result in blocks of text which would not be readable. The key was to have a format that could be easily readable and usable in the classroom. In Fox-Turnbull (2018), one participant had suggested that the teacher put the framework in a ring binder. This gave me the idea of having the different levels split into different sheets and putting it all in a binder or making them in a catalogue format that teacher could open and use whenever they wanted.

Each row would become a separate sheet. When the teacher was working on teaching 2D drawings, for example, they could use the strand about modelling only and not have to look at other strands. However, one strand in one sheet could result in many sheets. Hence, it was decided to cluster the strands to limit the number of sheets. Based on authentic technology practice and therefore, chronological use in the classroom, the strands were clustered in the following manner:

- The nature of technology: Characteristics of Technology and Characteristics of Technological Outcome (CT and CTO)
- Technological practice: Brief development and Planning for practice (BD and Planning for Practice (PP))
- Technological practice: Outcome Development and Evaluation (ODE)
- Technological knowledge: Technological Modelling and Technological products (Technological Modelling (TM) and Technological products (Tp))
- Technological knowledge: Technological Systems (TS)

As there were four levels, it could be possible to have one sheet for each level. However, giving flexibility to the teacher was considered important. They could have students working at different levels in the classroom and to accommodate differentiation, two levels were put in one sheet. There were a set of sheets for Level 1-2 and another set of sheets for Level 3-4. In all there were nine sheets as TS had only one sheet with all four levels.

For teachers working from Year 1-4, they would not need to refer to more than five sheets. However, teachers at Year 5-6 could need to refer to all nine sheets for different students and based on the teacher's objectives in the classroom. But for a specific lesson and specific focus in the unit, the teacher could decide which sheet to focus on. For example, if the teacher decided that they were going to summatively assess PP in that unit, they could refer only to two sheets for that unit.

Each page could have up to 32 questions and that could still be overwhelming for a teacher. Hence, each of the five behaviours was put in a different colour box so that visually, it was easy for the teacher to refer to a specific behaviour in their questioning. In the initial interview, the teachers were asked to focus only on couple of behaviours for a unit of technology so that the number of questions that they needed to refer, could be reduced to 6-12. The choice for the behaviours would be based on what teachers perceived as important for their students. An example of the Nature of technology sheet Level 1-2 can be seen in Figure 4.5. Appendix N shows the number of questions in each sheet and each behaviour.

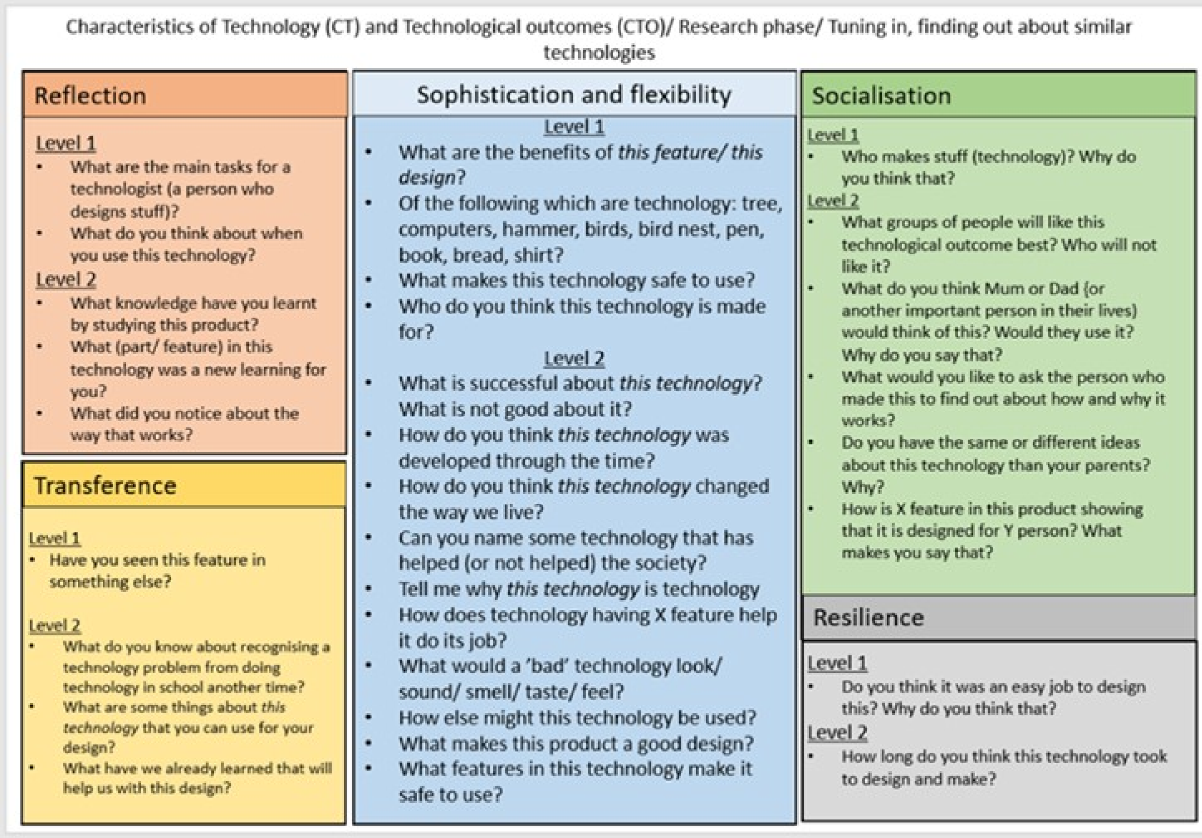
As can be seen in the figure, the different behaviours are in different colours. The level of the questions are indicated on the sheet. This QFT-P was presented to the teachers in Iteration round 2.

4.2.2 Iteration round 2

In Round 2, based on interviews with Jean and Sarah-Jane and through initial classroom observations, it emerged that the teachers were unfamiliar with the strands of technology. Hence, the titles were changed to reflect more familiar phrases that were in use in the classroom. For example, additional titles for CT and CTO sheet were "Research phase" and "Tuning in" and "Finding out about similar technologies". Table 4.1 shows all the modified titles.

The QFT-P was provided to Jean in the form of nine coloured sheets. Both teachers were shown this format and all nine sheets in an initial interview. Jean used this format in the classroom first in the plastic unit for two weeks. At the end of one week, I spoke to Jean based on observation in the classroom and how the teacher used the framework. Jean mentioned that she did not know how to use the framework for the next week. I suggested making a smaller list of questions for her from the framework as a temporary

Figure 4.5
Iteration Round 1 output



Characteristics of Technology (CT) and Technological outcomes (CTO)/ Research phase/ Tuning in, finding out about similar technologies

Reflection

Level 1
- What are the main tasks for a technologist (a person who designs stuff)?
- What do you think about when you use this technology?

Level 2
- What knowledge have you learnt by studying this product?
- What (part/ feature) in this technology was a new learning for you?
- What did you notice about the way that works?

Transference

Level 1
- Have you seen this feature in something else?

Level 2
- What do you know about recognising a technology problem from doing technology in school another time?
- What are some things about *this technology* that you can use for your design?
- What have we already learned that will help us with this design?

Sophistication and flexibility

Level 1
- What are the benefits of *this feature/ this design*?
- Of the following which are technology: tree, computers, hammer, birds, bird nest, pen, book, bread, shirt?
- What makes this technology safe to use?
- Who do you think this technology is made for?

Level 2
- What is successful about *this technology*? What is not good about it?
- How do you think *this technology* was developed through the time?
- How do you think *this technology* changed the way we live?
- Can you name some technology that has helped (or not helped) the society?
- Tell me why *this technology* is technology
- How does technology having X feature help it do its job?
- What would a 'bad' technology look/ sound/ smell/ taste/ feel?
- How else might this technology be used?
- What makes this product a good design?
- What features in this technology make it safe to use?

Socialisation

Level 1
- Who makes stuff (technology)? Why do you think that?

Level 2
- What groups of people will like this technological outcome best? Who will not like it?
- What do you think Mum or Dad (or another important person in their lives) would think of this? Would they use it? Why do you say that?
- What would you like to ask the person who made this to find out about how and why it works?
- Do you have the same or different ideas about this technology than your parents? Why?
- How is X feature in this product showing that it is designed for Y person? What makes you say that?

Resilience

Level 1
- Do you think it was an easy job to design this? Why do you think that?

Level 2
- How long do you think this technology took to design and make?

version. Jean agreed and chose to have questions from "Reflection" and "Sophistication and Flexibility".

4.2.3 Iteration round 3

Round 3 iteration was a temporary version of QFT-P to give me time to decide on what I could do next to make the QFT-P more user-friendly. For the temporary version, I picked questions based mainly from the behaviour "sophistication and flexibility" with the strands based on what Jean planned to work on in the upcoming two weeks. The idea was to have 1-2 questions with an extra 1-2 questions for students who came up to her frequently through the day. As Jean found it difficult to ask all students and keep track of different students' progress, a student checkbox was added so that Jean could track the students to whom she asked questions. This single sheet of questions was in a physical form that was designed to be carried around in the class (see Figure 4.6).

This iteration of the framework was to make Jean comfortable and was not considered as a modification of the main framework. The plan was to go back to the original framework and modify it in such a way that it was easier to find questions. While I worked on a

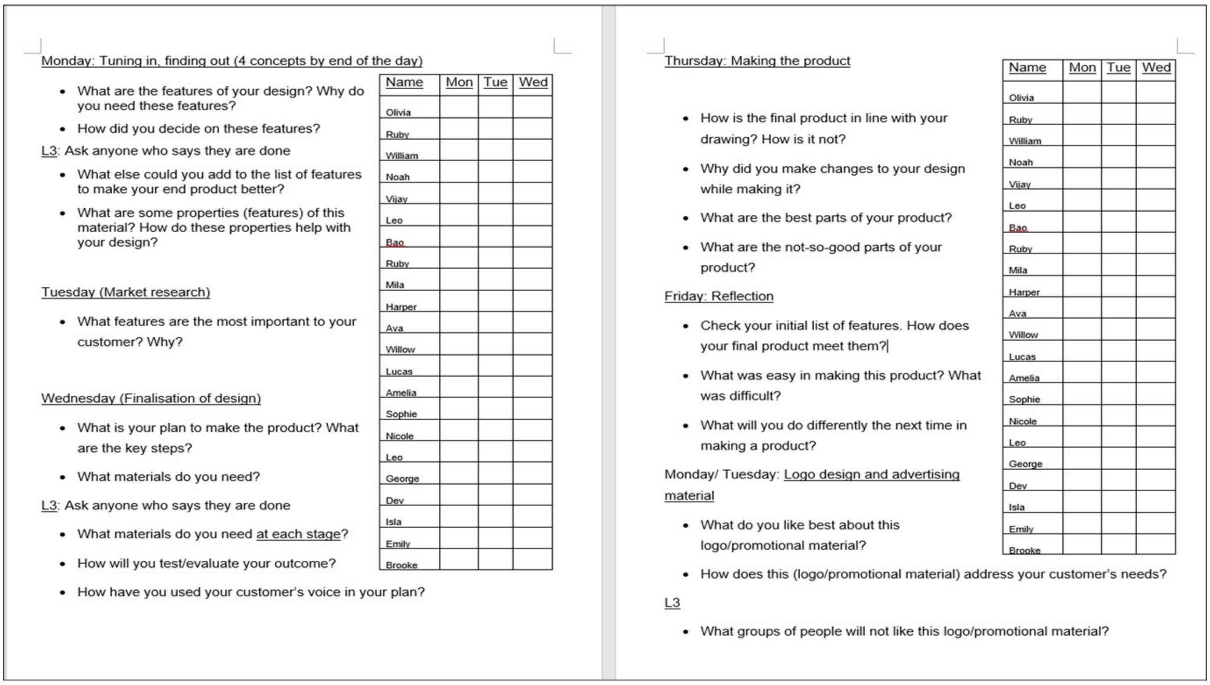
Table 4.1

Modified titles of the strands in the QFT-P

Component	New title
Characteristics of Technology (CT)/Characteristics of Technological Outcome (CTO)	Research phase/ Tuning in, finding out about similar technologies
Brief Development (BD)/Planning for Practice (PP)	Finding out, Sorting out/ Research about exact problem and planning
Outcome Development and Evaluation (ODE)	Drawing conclusions and reflection/ Making process and final reflection
Technological Modelling (TM)/Technological products (Tp)	Going further, Finding out/ Drawing the plan and material selection
Technological Systems (TS)	Technological systems

Figure 4.6

Round 3 - Temporary version of QFT-P



Monday: Tuning in, finding out (4 concepts by end of the day)

- What are the features of your design? Why do you need these features?
- How did you decide on these features?

L3: Ask anyone who says they are done

- What else could you add to the list of features to make your end product better?
- What are some properties (features) of this material? How do these properties help with your design?

Tuesday (Market research)

- What features are the most important to your customer? Why?

Wednesday (Finalisation of design)

- What is your plan to make the product? What are the key steps?
- What materials do you need?

L3: Ask anyone who says they are done

- What materials do you need at each stage?
- How will you test/evaluate your outcome?
- How have you used your customer's voice in your plan?

Name	Mon	Tue	Wed
Olivia			
Ruby			
William			
Noah			
Vijay			
Leo			
Bao			
Ruby			
Mila			
Harper			
Ava			
Willow			
Lucas			
Amelia			
Sophie			
Nicole			
Leo			
George			
Dev			
Isla			
Emily			
Brooke			

Thursday: Making the product

- How is the final product in line with your drawing? How is it not?
- Why did you make changes to your design while making it?
- What are the best parts of your product?
- What are the not-so-good parts of your product?

Friday: Reflection

- Check your initial list of features. How does your final product meet them?
- What was easy in making this product? What was difficult?
- What will you do differently the next time in making a product?

Monday/ Tuesday: Logo design and advertising material

- What do you like best about this logo/promotional material?
- How does this (logo/promotional material) address your customer's needs?

L3

- What groups of people will not like this logo/promotional material?

Name	Mon	Tue	Wed
Olivia			
Ruby			
William			
Noah			
Vijay			
Leo			
Bao			
Ruby			
Mila			
Harper			
Ava			
Willow			
Lucas			
Amelia			
Sophie			
Nicole			
Leo			
George			
Dev			
Isla			
Emily			
Brooke			

more accessible QFT-P version, the modified version was a temporary fix.

4.2.4 Iteration round 4

Jean started the cardboard unit when she had the temporary version of the QFT-P. As mentioned before, the cardboard unit was three weeks long instead of two weeks that the previous plastic unit had lasted. It took me almost till end of the cardboard unit to modify and print a new version of the QFT-P. Providing this new format started the fourth round iteration.

In Round 4, Jean was offered a card-version of the QFT-P. This version did not have cards about Technological Systems (TS) since both teachers had indicated that they were not familiar with TS. The idea behind the card version was to have simple cards with behaviour and strands separated so that there were limited number of questions on each. In total there were 41 cards. Only eight of the 41 cards had more than seven questions. The maximum number of questions in any one card was 14. Appendix P shows the different cards and number of questions. The idea behind designing the cards this way was to provide flexibility to the teachers to separate and focus only on specific cards based on their interest in specific strand or behaviour. However, the teachers would still have many options for multiple years with different levels of students.

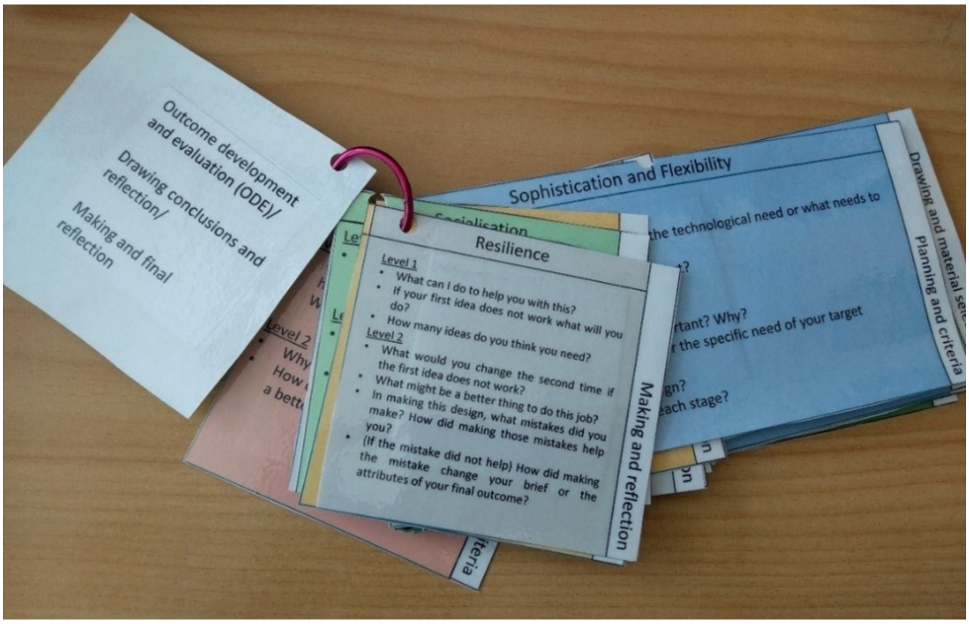
The long bulky titles were modified to something short and generic, and the full title was placed at the back of the cards to ensure retention of meaning. All these cards were put in a ring holder so that they could be flipped through easily or removed if the teachers were not interested in any individual cards for the current unit. Example of these cards can be seen in Figure 4.7.

4.2.5 Iteration round 5

As the new version was given to Jean almost at the end of the second observed unit, there could be no more development with Jean.

In Round 5, the card version was offered to Sarah-Jane who initially commented that there were too many questions, and it was quite complicated. After the observation of the first lesson in the unit where she did not ask any question from the QFT-P, she mentioned again that it was overwhelming to use the QFT-P, and in response to this comment, I offered only four cards. The plan was to add more cards as she got comfortable with using the framework. The four cards were chosen based on what she was planning to focus during the unit and the behaviours she had chosen - Level 1-4 of TM-Tp and ODE

Figure 4.7
Version 4: Card version of QFT-P



on the behaviour "Sophistication and Flexibility". Later in the unit I added the cards for "Reflection" for the same components TM-Tp and ODE Level 1-4. As the observation ended at Minerva, this was the last round of iteration. At the end of this round, the card version of QFT-P stayed but was offered few at a time.

4.2.6 Questions asked during different iterations

I anticipated that teachers would give feedback on specific types of question or focus on specific behaviours and that this feedback could give more information on what the next round of development of the QFT-P could be. However, what defined one iteration from another was the format of the QFT-P to improve the user-friendliness of the QFT-P. The main feedback from the teachers that led to the change in the format of QFT-P was the difficulty of use and the teachers being overwhelmed with the huge number of questions. Both these issues were predicted from the beginning and hence, in the first iteration, the format was changed from the original version designed by Fox-Turnbull. However, the feedback from the teacher caused nine A4 sheets to become 41 cards of approximately A6 size. The teachers in this study did not give any feedback on questions specifically. Hence, the number of questions in iteration rounds 2-5 iteration did not change.

Analysis of the classroom audios reveal that Jean asked 28 questions from the QFT-P and Sarah-Jane asked 15 questions from the framework. These questions were asked multiple times in one unit of TE. Of these, the teachers asked most questions from Technological Practice and majority of the questions they asked were from the component ODE. Most questions were from the behaviour "Sophistication and Flexibility" followed by the questions from the behaviour "Reflection".

Jean asked most questions from the QFT-P as reflection questions every week. The answers to the reflection questions would be in a blog/vlog form which the students uploaded in the school-wide system either in groups or individually. Jean approved the blog or vlog before the parents could view them. Jean did not discuss the answers with the students or follow-up if a student did not upload the blog/vlog although the initial intent was to view the videos/read the blogs and comment to the students. In the beginning I helped Jean pick out questions for reflection but by the end of the term, Jean picked out questions on her own and did not need my support. Sarah-Jane did not need support with picking questions from QFT-P at any time.

The final version at the end of the study is the card version of the QFT-P. The iterations of the QFT-P indicate that teachers found it difficult to focus on the content unless the format of the QFT-P could be used easily in the classroom. The teachers did not comment on the content of the QFT-P except for Sarah-Jane's comment on the need for simplified language. Even though I was explicit in asking teachers to choose one strand and one behaviour in the paper version of the QFT-P when they needed to use the QFT-P in the classroom, the teachers could not avoid being overwhelmed by all the questions in the single page. It is likely that in the initial interview when they had to read the whole QFT-P to be able to comment on its usefulness to them, they retained in their mind the experience of feeling overwhelmed by the QFT-P.

In the next chapter we discuss the findings related to using the QFT-P in the classroom.

Chapter 5

Use of QFT-P in the classroom

> ...[Teachers] must, in addition, have that sympathetic understanding of individuals as individuals which gives him [sic] an idea of what is actually going on in the minds of those who are learning. (Dewey, 1997, p. 23-25)

In the methodology chapter, the analytical framework was explained as analysis of a technological outcome. The purpose the QFT-P was to serve as a formative assessment tool for primary teachers in NZ. In addition to the purpose, some desirable attributes were described in detail. To restate, the attributes of the QFT-P are:

- Rich and deep dialogue between the teacher and the student(s)
- Teachers develop technological content knowledge
- No increase in the workload of the teacher
- User friendliness
- Flexibility
- Near zero cost
- Positive impact on the student learning

The attribute related to student learning required the analysis of a completely different data source (student work) and hence, that evidence is presented separately in the next chapter. Before the findings of the study are presented, it is necessary to understand teacher beliefs about technology and teaching as it influences how they approach TE in the classroom. The next section after teacher beliefs is the evidence of using QFT-P as a formative assessment tool. The rest of the chapter presents the evidence against the attributes stated above. Each section delves into one of the attributes of QFT-P.

5.1 Teacher beliefs and knowledge

The analysis of transcripts of teacher interviews, observation notes, and classroom teaching resources were the data sources for findings related to teacher beliefs and teacher knowledge. Audios and videos from the classroom added additional depth and were used for triangulating the data.

Studies show that it is necessary to understand teacher beliefs about learning and teaching to understand their classroom practice (Helms, 1998; Reznitskaya & Wilkinson, 2015; Schoenfeld, 1998; Wilkinson et al., 2017). The beliefs of the two teachers in this study are presented in the following sections.

5.1.1 Beliefs about teaching and a teacher's role

Beginning with Jean's beliefs this section presents both participant teachers' beliefs about the aims, purpose or nature of teaching and a teacher's role. Jean asserted that she believed in teaching the whole child. She stated, "*other parts of students determine how well they will learn academic (objectives)*" (Interview 1 with Jean, lines 10-11). By other parts, Jean was referring to feeling safe and cared for in the class. Jean demonstrated this by greeting everyone in the classroom and having circle time to discuss their weekend every Monday. She also allowed students to bring non-academic talents to classroom for demonstration – for example, two students performed on a Chinese instrument during one of the classes and another student taught the rest of the class some basic signs in NZ sign language.

Jean said that she wanted to prepare the students for the future and to not let students be limited by her knowledge or ability. Jean explained that she preferred teaching through giving students experience and that talking at them was not very helpful. She continued, although providing experiences could take more time, she believed it was a more effective form of learning. Jean indicated that she favoured questioning students and/or letting them talk to each other to figure things out. Jean explained that students' success will be "*determined by how well they interact with others, how well they can be creative, how well they will communicate, how well they can express their emotions, talk to people about their feelings and understand their own passions*" (Interview 1 with Jean, lines 14-16). She believed that reading, writing, and maths was a very small part of a child's successful future.

Sarah-Jane held many of the same beliefs as Jean. Sarah-Jane stated that she strongly believed in preparing students for the 21st century. She wanted them to be self-managers, and to communicate and collaborate with each other. She valued problem solving and critical thinking. Sarah-Jane commented that she wanted students to start taking responsibility themselves and start learning on their own. She mentioned that she co-constructed classroom expectations along with the students and expected them to meet these every day. Sarah-Jane mentioned that she collected student voices regularly and talked to students to solve any classroom issues. Like Jean, Sarah-Jane stated that she wanted students to feel safe in the classroom and that she wanted them to "*. . . feel valued and they belong in this learning space*" (Interview 1 with Sarah-Jane, lines 39-40).

Jean saw a teacher's role as setting up the learning programme of experiences where students could learn by themselves or with each other. She wanted to set up learning activities that incorporated the students' interest and she wanted to scaffold learning for all students but also provide a small amount of explicit teaching where it was needed. She described the teacher's role as:

> It was a balancing act - know what the kids are going to say, feed in to the kids and get the result of what we wanted, where we wanted to go with it. Because if they went on a strange tangent, this is just not going to go anywhere. As a teacher, it's your job to veer them. Tell them it's a dead end. You don't want set them up for failure. [Although] Sometimes some failure is good (Interview 1 with Jean, lines 236-240).

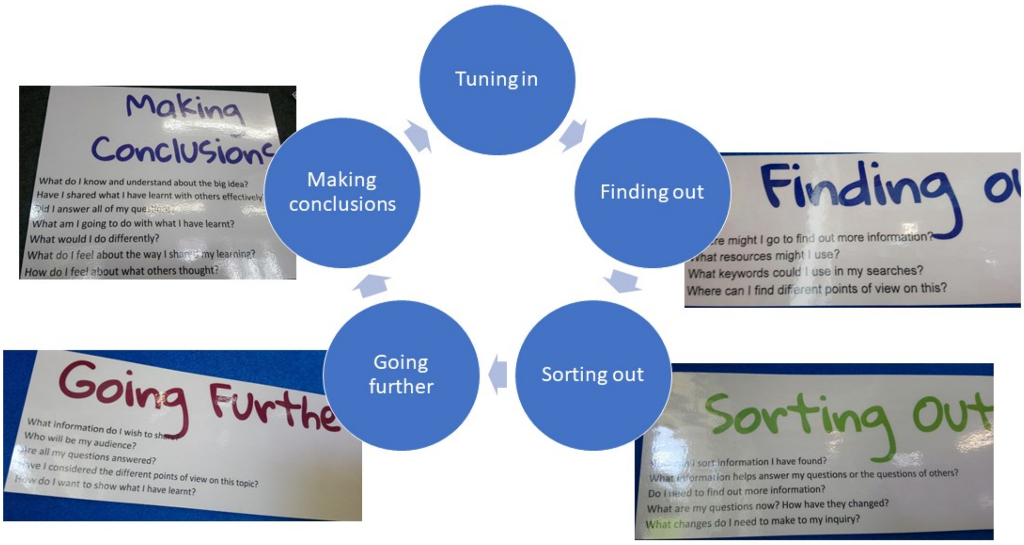
Sarah-Jane saw her role as a teacher to encompass a response to wide variety of student needs - as a role model, providing emotional support, nurturing students, providing differentiation, facilitating, and guiding. She wanted her students to be prepared for the next phase in schooling while becoming independent learners. She wanted students to realise that perseverance, challenges, and initial failures led to learning. She wanted them to have high expectations of themselves and have a sense of achievement.

Both teachers, thus, thought of teaching as beyond instructing on certain subjects and their role as teachers as facilitators and provider of experiences to the students.

5.1.2 Teacher's belief and knowledge of technology education

Beliefs about TE are known to be influential to how teachers teach technology in the classroom (Doyle et al., 2019). As the teacher's beliefs about TE are expected to influence their adoption and use of the QFT-P, it is important to understand their beliefs on the role of TE in their primary classroom, their experience of teaching TE and their knowledge of TE in relation to the NZC. The two teachers admitted in the initial interview that they did not refer to the curriculum documents for technology frequently. They also said that they did not have any formal or informal professional development on technology education as in-service teachers. Both teachers had less than one year experience in teaching technology.

Figure 5.1
Inquiry cycle at Athena



The two teachers approached TE in different ways. Jean used a fully integrated unit and she taught technology with all other subjects in a PBL approach. Jean also believed in teaching the inquiry cycle which she equated with design cycle that she had learnt in her schooling years. Jean explained in the initial interview that design cycle (shown in Figure 5.1) was the same as "learning to learn" and in her opinion, it was the best way to learn. She felt that it was the design cycle combined with authentic projects that made a difference and would give students *mana* (respect) and confidence. Jean believed that in the past, when students were involved in real contexts, the experience was "*really powerful for them*" (Interview 1 with Jean, line 263) and that there were better results from the students. Jean defined technology as "*the design process but in a hands-on way*", "*Technology is when they are physically manipulating stuff*" (Interview 1 with Jean, lines 312-313). She observed that when the students understood the purpose, they were engaged. When asked to draw the technology process, Jean drew the figure as shown in Figure 5.2. The technology process Jean envisaged was similar to the inquiry cycle she used in the classroom.

In the figure, it can be seen that Jean drew TE as the inquiry cycle with the first step as tuning in, followed by concepts, development, final, and reflection. However, she added reflection at every stage on the arrows showing that reflection is a critical step at every stage. When I gave her additional words from the NZC, and TK in between concepts and development and TP to the final and reflection phase in the cycle. She added NT

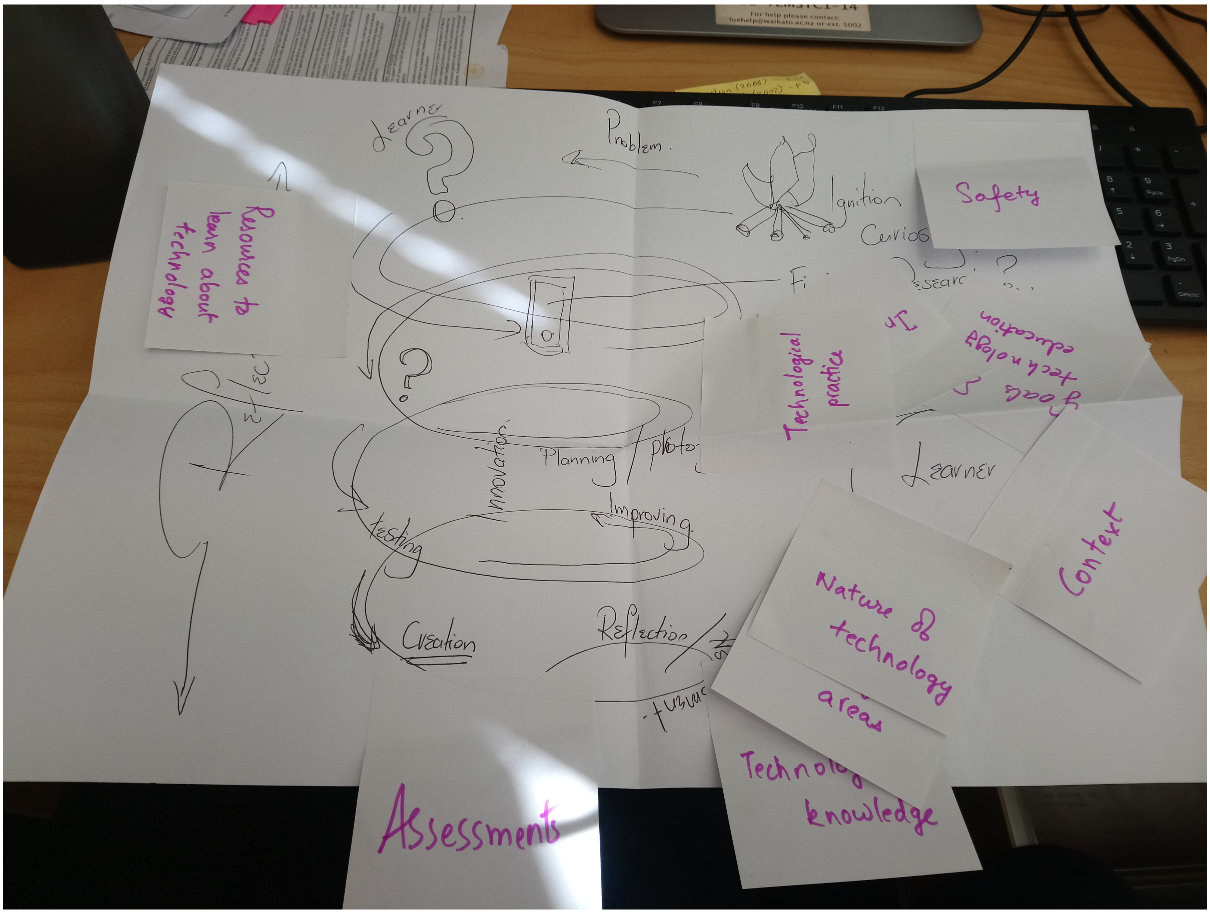
Figure 5.2
Technology process drawn by Jean

outside the whole cycle.

Although Jean was motivated and believed in teaching holistically, in later interviews, Jean often mentioned that she felt pressured to focus on reading, writing and maths. Jean frequently mentioned during observations that she was worried about not doing enough maths or reading. Jean mentioned that the reason for her worry about reading, writing and maths focus resulted from having to report these three in the half-yearly report cards to the students' *whanau* (family/guardians).

Sarah-Jane was teaching technology as part of science, technology, engineering, arts, and maths (STEAM) once a week. Since she taught reading, writing, maths at other times during the school day, she was not concerned with those during the STEAM time. Her idea of using STEAM was to promote 21st-century skills. In an initial interview, when I asked her the difference between STEAM and technology, she said that they were the same. She explained "*Technology comes in many guises. Is it digital technology, engineering or building technology? Is it food based? For me, it is almost*

Figure 5.3
Technology process drawn by Jean



about making, building, creating and innovating" (Interview 1 with Sarah-Jane, lines 110-113). When asked to draw the technology process, she drew Figure 5.3. The figure shows that Sarah-Jane thought of the technology process as a never ending spiral upwards.

Sarah-Jane's spiral started with ignition, followed by planning, improving, testing, creation, and reflection. She then added reflection across the whole spiral as if to indicate that reflection happens at each stage. She added assessment to the last stage of reflection. When given words from the curriculum, she added TP between ignition and planning and TK to the reflection phase. She added NT outside the spiral.

In later interviews, however, Sarah-Jane mentioned that STEAM approach is more than technology. It is likely that her thinking evolved from the initial interview and she said that technology was just one access point into STEAM and over the year, Sarah-Jane used other access points like science. For example, she mentioned that if she chose Science as entry point, she conducted experiments and asked students to design experiments as outcome. Sarah-Jane believed that teaching using the STEAM approach kept the students engaged and the students were not in a hurry to leave school at the end of the day now that she used this approach. She also mentioned that students were starting to become independent learners and were doing some of the work at home, which was unheard off, she said, in that school. She felt the STEAM and making products gave all students an opportunity to learn and provided different "access points" to feel success at school. Through the unit that was the focus for this research, Sarah-Jane pointed out students who she felt benefited from the STEAM approach and how engaged those students were.

The next section offers evidence for the attributes of QFT-P in the classroom as formative assessment.

5.2 Interactive Formative Assessment in Technology Education

The intention behind the introduction of the QFT-P to the two primary TE classrooms was the identified need to use high-level questions for formative assessment. Across both teachers, a total of 116 instances of dialogues were identified for analysis. This section presents the findings from the analysis of these dialogues with the first section providing the evidence for use of QFT-P as a formative assessment tool in the classroom.

5.2.1 Use of QFT-P as formative assessment tool

The IFA cycle described in literature suggests that there are three key steps to formative assessment (Cowie & Bell, 1999; Ruiz-Primo & Furtak, 2007). The first step is the teacher eliciting information from the student. The teachers in this study did this by asking questions from the QFT-P. The second step is the response of the students. In this case, the student response continued the dialogue. In the third step, the teacher responded to the information provided by the student by using the student response or providing feedback. Based on literature and analysis of data of the study, the teacher feedback was categorised as asking for clarification, developing student thinking, redirecting student thinking, reinforcing learning, providing praise or encouragement, and providing support for next step. Evidence for each of these feedback categories follow.

Asking for clarification

In many instances in this study, when a student responded, the teacher may not be have been sure what the student meant and needed further information from the student to gauge where their learning was, or to encourage clear communication. In that case, the teacher asked a further question for clarification or made a sound to indicate that they are listening thus inviting the students to continue with their explanation. In the dialogue below (T2-Week3-min 33:10) between Sarah-Jane and Mia and Charlie's group, Sarah-Jane asked a question for clarification when students were researching the materials for making a water-filter.

> Sarah-Jane: What do you need to know?
> Charlie: What materials are going to go where?
> Sarah-Jane: Mia, you can reply.
> Mia: Put the materials in the right place.
> Sarah-Jane: When you say materials, what materials?
> Charlie: Charcoal, sand.

In this case, Sarah-Jane needed further clarity on which materials the students were referring to and asked the question, "*When you say materials, what materials?*". The teacher may restate the question if the student's response is incomplete or unclear. She also invited Mia to contribute. In the dialogue below (T1-Week3day2-M3-min 16:30), Jean was talking to George about the three design ideas he had for action figures.

> Jean: Why did you choose this design?
> George: Because it is my favourite.
> Jean: Why is it your favourite? (*George does not respond*)
> Jean: Why would you choose this one and not this one?
> George: (*Part of the answer inaudible*)...this one looks good (pointing to one), this one looks cool (pointing to another design), this one looks evil and that's why I like it.

Here Jean restated her question to understand the answer to the original question "Why did you choose this design?". Restating the question in a different way can help the students understand the intent behind the question better. If the teacher is clear about the students' reply, they may ask a further question or offer a statement to develop student thinking.

Developing student thinking

The framework aided teachers to ask further questions in response to the students' answers in order to develop their thinking. Developing the thinking could mean that the teacher led the student into exploring their learning further, making connections to past learning or their funds of knowledge, or comparing/contrasting their ideas with others. The student may have been able to reply immediately, or the teacher offered more time to discuss or research the answers.

In the dialogue below (T1-Week3Day2-M1-min 33:22), Jean discussed their plan with Ava, Mila, and Ruby to make a doll house for the cardboard unit.

> Jean: What is the difference between these two designs?
> Ava: One of the designs will be easier to make as it is less complex.
> Mila: We can make it faster and then add more details in it.
> Jean: Why are the details important?
> Mila: So that we can make a cute little house.
> Jean: Why do you need the house to be cute?
> Ruby: So that someone will buy it.
> Jean: Who will buy it?
> Group: Juniors.
> Jean: Who is the customer?
> Group: Seniors.

Jean asked a series of questions to develop the student thinking and led them away from making something of their own interest instead of focussing on the customer. Here, Jean accomplished that by asking 'why' questions.

In another instance, Sarah-Jane engaged in a dialogue with Aisha, Kayla, and another student about their water-filter design (T2-Week2-min 9:31).

> Sarah-Jane: So, tell me how it works. What materials are you using?
> Aisha: We are using sand, pebble, and charcoal. We are going to make a mixture of sand and pebbles to make rocky sand and then wool and that's it.
> Sarah-Jane: Is this the order you put it in?
> Aisha: Yes.
> Sarah-Jane: Why did you choose this order?
> Aisha: We figured it should go through the sand last.
> Sarah-Jane: Why? (*No reply for some time*).
> Sarah-Jane: Because it is smoother/ soft?
> Group: Yes.
> Sarah-Jane: I am happy for you to start your design.

In this dialogue, Sarah-Jane asked further questions as her aim was to make students aware of the reasons for using any of the material in the water-filter. In the end, when the students were unable to respond to one of her questions, she gave an answer so that the students could work on making their design. Sometimes, the teacher may redirect the student thinking with a question or a statement.

Redirecting student thinking

Sometimes the student responses indicated that their learning is going in a different direction than the learning goals or the student was misunderstanding some aspect of their learning. The dialogue normally began with a framework question and the teacher on recognising the need to redirect the student thinking, the teacher used statements or rephrased the questions to redirect the student learning. In the dialogue below (T1-Week3day5-M1-2-min 1:50), Jean asked Noah, Vijay, and Dev about what they learned from doing market research.

> Jean: What have you learnt from your market research?
> Group: We need support if we are going to make it.
> Jean: Is that what you learnt from the market research?
> Group: Because our last design, it kept falling apart at the arms and it was NZD 5. I don't think this can be NZD 5 worth.
> Jean: You are telling me you need supports. That learning has not come from market research. That learning has come from the last product. Because you think you need to make it strong enough? Is that what your market told you? Your consumers told you?
> Group: Yes
> Jean: Oh, ok. That kind of like is market research then. What did you learn from interviewing your customers?

Jean redirected the learning in two instances here. When the group replies that they did not think their current product could be NZD 5, Jean brought the focus back to the market research insights. The second time, the students confused customer feedback with market research. Jean asked the question multiple times and finally rephrased the question as "*What did you learn from interviewing your customers*?" to get the answer to the market research question. At times, it may be important to use questioning to reinforce the learning.

Reinforcing learning

During or after the dialogue, the teacher could sometimes reinforce the learning by re-stating some of the key points that emerged in the dialogue. Jean, in her dialogue with Ava, Mila, and Ruby (T1-Week3Day2-M3 min 22:16) discussed the key feature of the design. This dialogue began with questions from the QFT-P about the dollhouse the three of them had decided to build.

> Jean: What is the most important feature of your design for your customer, do you think?
> (Answer inaudible.)
> Jean: What? Don't you want it to fall?
> Mila: Stability.
> Jean: Yes. That is a feature - how stable it is. A design that is stable is better than a design that is very creative but flimsy and would fall apart. (inaudible

> conversation) Good work. It seems like you are very scientific about your feature and that stability is going to be very important to you. Write your market research questions now.

Jean asked the three of them about the most important feature in their design and the group seems to have replied that they did not want their design to break apart. When Jean seems to repeat what they told her, Mila replies with a word "stability" - giving a technical term for what they considered the most important feature. Jean at this point reinforces the importance of stability in the design.

In the dialogue between Sarah-Jane and Blake, Amir, and another student (T2-Week4-min 34:20), Sarah-Jane discussed how the students could work better together the next time reinforcing their learning about collaboration.

> Sarah-Jane: So, the actual sharing? Did you have a talk with each other?
> Group: Yes.
> Sarah-Jane: What will you do about that next time?
> Blake: Try to work together more.
> Sarah-Jane: Yes, but what would that look like?
> Student: Before we start, we will share ideas and we can agree on things and disagree on things.
> Sarah-Jane: Nice!
> Student: We would have an idea of what others are thinking.
> Sarah-Jane: So next time, everyone gets to share. This is why collaboration is so good. I listen to one person's idea, and it sparked another idea. Before you even start, you grade the expectations of the group. You have a treaty among the group. What do you think about that? So, you all agree on a treaty on how the group has to be run? It doesn't have to take more than 5 minutes, right?
> Amir: It will take two minutes.
> Sarah-Jane: Yes. Good. For instance, like you said, everyone gets to share their ideas first and then you talk about it. Nice thinking.

This dialogue began with a question from QFT-P. Some time into the dialogue, Sarah-Jane was seeking to understand why the students struggled to work together. She then encouraged the students to think deeply about what they could do better next time. In the end, she suggested the idea of a treaty and reinforced the learning from the dialogue in the end "*Everyone gets to share their ideas first and then you talk about it*". Here Sarah-Jane also used praise at the end of the dialogue.

Providing praise or encouragement

Teachers often provide praise and encouragement in their dialogue with students. We can see it in the last two dialogue presented in the section above when Jean said, "*It* *is a nice plan*" and Sarah-Jane said, "*Nice thinking*". Another way to provide specific praise is to link it to the classroom goals like Sarah-Jane did in the dialogue given below (T2-Week2-min 14:15)

> Sarah-Jane: So, what does charcoal do?
> Someone in the group: We did some research and charcoal helps to filter.
> Sarah-Jane: Good. I am happy for you to make your design. You guys are 21st century learners. You guys have done problem solving, you have actively participated. What else have you done?
> Student: We have (inaudible)
> Sarah-Jane: You have been kind to each other as well. But what I like is your critical thinking skills. You are actively thinking about what you are doing. It is really important.

Sarah-Jane praised the students for being 21st century learners – an important goal for her in the classroom. She reinforced the qualities of 21st century learners by explaining that 21st century learners problem-solve, participate actively and think critically.

Providing support for next step

It is critical for teachers to provide support for students about going forward in their learning. At the end of every dialogue, students are either instructed on what to do next or decide the next steps in collaboration with the teacher. In this section, with most instances of dialogue, the next step is discussed. For example, when Sarah-Jane said "*I am happy for you to start your design*" or when Jean said "*That is a good plan*". Further instances of the discussion on the next step can be seen in the dialogue between Sarah-Jane and some students (T2-Week2-min 23:15).

> Sarah-Jane: So why do you need two bottles?
> Students think out loud but give no answer.
> Sarah-Jane: Go discuss that part of your design and come back.

Here, Sarah-Jane asked the students to go back and discuss why they needed two bottles in their design. In the dialogue below between Jean, Emily, and Brooke (T1-Week3Day1-A1-min 10:34), Jean asked about what Emily and Brooke were planning to make for their cardboard cycle.

> Emily: It is a toy.
> Jean: It needs a purpose, and it is quite safe design. Speak to Brooke.
> Emily: I was also planning if we can make this clothes rack for the minion.
> Jean: It is bit more creative but think about the purpose. Decoration cannot be a purpose.

Jean wanted students to think about a "creative" design and not a "safe" design. She had a whole class discussion about what it meant to be creative and safe. She asked the whole class, "How creative you are being with your ideas? How safe you are being with your ideas? Think about your last idea how creative you were with your ideas? Your designs need to meet the brief...and you need to challenge yourself to be creative" (T1-Week3Day1-M3 min 1:30). In continuation to the whole class discussion, she spoke to Emily individually and explained that she needed to think of a more creative design than making a minion.

The instances of dialogue originating from the QFT-P serve as evidence that the QFT-P can be used as formative assessment tool by the teachers. The next step of analysis is to present evidence for the attributes.

5.2.2 Deep and rich dialogue between teacher and students

When designing of the Technology Observation and Conversation Framework (TOCF) (Fox-Turnbull, 2018), Fox-Turnbull recommended the use of the questions in TOCF as starting point in the dialogue between teacher and students and the intention was retained in the QFT-P. The first step to analyse evidence for this attribute was to isolate dialogues that began with QFT-P questions asked by the teacher to a student or groups of students orally in the classroom, from the written responses to the teachers' questions from the framework, and the video reflections of students to the questions from the QFT-P.

There were two distinct kinds of classroom talk in this study that originated with questions from the QFT-P – the oral dialogue and the written/video reflections. On analysing the video or written reflections of the students against oral dialogue, I noticed that oral dialogue was longer and contained more authentic conversations that mirrored regular speech. Here, authentic conversation refers to conversations where the teacher is not seeking a pre-determined answer. When the teacher initiated the conversation by asking a question, the teacher did not expect a specific response as every student had a different plan for making. As the response is unexpected, the teacher deliberated on the student's response and offered thoughtful feedback and this back-and-forth ended when a way-forward was suggested by the teacher or student. An example of such a dialogue is presented below between Jean and Sophie (T1-Week3day4-M3-2-min 34:25).

> Jean: What features were most important to your customer?
> Sophie: The place for storage, I guess.
> Jean: Why do you think the storage place was most important?
> Sophie: Because of space saving and so they can put money inside.

Jean: How big will this be?
Sophie: I don't have exact measurements.
Jean: I am interested to know how you will attach these arms? There are lot of areas of attachments - arms to the body, legs to the body. Can you draw it carefully and show me how you are going to do it?

In this dialogue, Jean began with a QFT-P question about the most important feature to the customer. Sophie who was planning to make a robot stationary holder spoke about how she planned to include a storage space in line with the feedback she had received from the market research. Jean wondered why the storage space could have been important - maybe, asking for further clarification or checking for a deeper understanding of the customer need. Sophie responds with the idea that it would be space saving and that they could maybe store money in the storage space. Jean seems to accept this answer and asked for clarification on the size of the storage space to which Sophie replies that she does not have the measurements. Jean accepts this answer for the time being and asks for clarification for another part of the design - attaching the limbs to the body. The answer to this question cannot be explained without aid of drawings and hence, Jean has offered the next step that she wants Sophie to work on - drawing how the attachments will be achieved in the design. The dialogue has multiple turns of conversation - alternating between student response and feedback. Even a relatively small dialogue lasting around a minute, necessitated going beyond the first question from the QFT-P and impelled Jean to engage with the responses and extend the dialogue.

Dialogue containing multi-turn conversation can be carried out in scenarios with groups of students and whole-class discussions and many examples were available in this study as well. An example of a whole class dialogue is presented in Table 5.1. This whole class dialogue is longer and took around 10 minutes and occurred at Minerva in Sarah-Jane's class (T2-Week3-min 0:00), after students had made one prototype for the water-filter and had to redesign the prototype a second time after carrying out research using Google. To ensure that students achieved success in the research process, Sarah-Jane discussed the search terms the students could use in their online search. Students had searched online before during other units and hence, this discussion was meant to extend existing knowledge gained through experience from previous lessons.

Table 5.1: Whole class dialogue at Minerva along with analysis of feedback for every turn

Dialogue in the classroom	Analysis of feedback offered at every turn
Sarah-Jane: What kinds of questions will you google [to research water-filter]? Kayla?	Sarah-Jane asks a specific student for response and gives her feedback that her question was not correct and asked another student for a response.
Kayla: What are the steps?	
Sarah-Jane: Of what?	
Sheryl: of making a water filter?	
Sarah-Jane: Not really. Have a think again. Thomas?	To Thomas, Sarah-Jane listens to the answer and asks for further clarification. Thomas clarifies his question by making it more precise and Sarah-Jane offers feedback by saying it was correct and writing the response on the blackboard for other students' reference.
Thomas: What does sand do?	
Sarah-Jane: Sand do in?	
Thomas: In the filtering process?	
Sarah-Jane: Excellent (writing the question on the board)	
Sarah-Jane: I want you to think of questions to put in Google. Alice?	Sarah-Jane continues asking the same question to other students.
Alice: How does the water filter work?	
Sarah-Jane: I actually quite like that question. Jay?	To Alice, she again says that the question was good and asks Jay.
Jay: What do coffee filters do?	
Sarah-Jane: Can you finish the question?	
Jay: In the filter?	Sarah-Jane prompts further clarification from Jay - reinforcing the learning about precise questioning in Google. She offers praise by writing Jay's question on the board.

Continued on next page

Table 5.1: Whole class dialogue at Minerva along with analysis of feedback for every turn (Continued)

Dialogue in the classroom	Analysis of feedback offered at every turn
Sarah-Jane writing the question on the board. Mia?	
Mia: How do all the components work?	When a student responds, Sarah-Jane prompts deeper thinking in asking to break-down the question for purpose of researching online.
Sarah-Jane: That is a huge question. How will you break that down? Think of the components. For example, those who used sand in their design, sand was a component. Charcoal was a component. Alia?	Sarah-Jane offers a new terminology "components" here and encourages its use.
Alia: What (inaudible) and why?	
Sarah-Jane: Be specific with the question.	Sarah-Jane asks Alia to be more specific
Alia: What....?	
Sarah-Jane: I am sure that is going to be a very good question. See if you can finish it.	Sarah-Jane offers encouragement by saying that it will be a good question once Alia finishes the question.
Sarah-Jane: Jim? You had a really good question last week. And it was about charcoal.	Sarah-Jane prompts another student Jim by reminding him of a question he had asked during a previous lesson.
Multiple students thinking aloud: Why do you need charcoal in the water filter?	
Aisha: What is pebble used for?	When Aisha offers a response, Sarah-Jane gives a response prompting deeper thinking in the student.
Sarah-Jane: To make roads.	
Aisha: What is pebble used for in a water filter?	

Continued on next page

Table 5.1: Whole class dialogue at Minerva along with analysis of feedback for every turn (Continued)

Dialogue in the classroom	Analysis of feedback offered at every turn
Sarah-Jane: See, you have to be specific with your question. Blake?	Sarah-Jane reinforces the learning that the search questions must be very specific.
Blake: What is the sequence to put…?	
Sarah-Jane: Do you want me to help you word that? So 1. You have to know which components?	Sarah-Jane offers help to another student to word a question better. Her suggestion is not accepted by another student who offers a different wording which Sarah-Jane accepts by writing it on the board.
And 2. You have to know the order of the components. No? Aisha?	
Aisha: Which components do you put first and last in the filtering system and why?	
Sarah-Jane: (Writing down the question) I am hoping that these questions will help you get started with your research….It is your job as a group that everyone understands what you are doing and why you are doing it. So, as a group, part of collaboration is that you guys rely on each other to meet your goal. So your goal is to redesign your prototype and make it. So you guys have to rely on each other to get the job done...You might need to discuss how your group is going to operate. Off you go.	Sarah-Jane tells the students the next steps for working on their water-filter design.

In the dialogue between teacher and students presented, Sarah-Jane offered feedback at every step. In contrast, when students were asked to write their responses in an online blog to questions from the QFT-P, student responses were short and there was no further follow-up as exemplified below.

> Question: What are the 5 key steps/stages of making your product? (T1-Week3day5)

Bao (typed answer in the online blog): Planning, research, doing final design, market research
George (typed answer in the online blog): 1.Concepts 2.Not sure 3.Not Sure 4. Final design 5. Making it
Sophie (typed answer in the online blog): Painting, cutting, gluing, trying to find the measurements and getting it to stand

As seen in the written responses, Bao has mentioned four steps instead of five - he has forgotten to add anything related to making the technological outcome. George wrote "*not sure*". Sophie mentioned five stages, but they seem to be in incorrect order. She indicated that she would paint before she cut, glued, or measured. In fact, Sophie wrote the measurements in the perspective drawing that she did before making. Evidently, "*trying to find measurements*" was the first step Sophie completed. Arguably, Sophie has not put the key stages in chronological order and has possibly not demonstrated her understanding of the need to plan before the making.

In contrast, the same question asked in a dialogue between Jean, Ava, Mila, and Ruby (who were making a dollhouse) - led to a longer dialogue (T1-Week3Day4-M1-1).

Jean: If you have to tell me 5 stages of the design to make it, what will be the 5 stages?
Ava, Mila and Ruby thinking out aloud with each other: 1. Making/ putting the structures, 2. Making the roof, 3. Details will be last.
Jean: So you think it is most important to do the main. . . ?
Ava: The main structure.
Mila: That's what builders do. They do the main structure.
Ava: The main support.
Mila: If you don't have support, you see the beams in the class? I don't know, if an earthquake came, the whole class roof will fall down. The beams makes it stronger.

Ava, Mila, and Ruby were talking amongst themselves more than with Jean. But through the dialogue, they demonstrate that they understand the importance in building structures and doing the main support and importance of the main support in a structure. The conversation about the stages to make the technological outcome continued below as part of a longer conversation.

Jean: So I am writing down so that we are all clear: Stage 1 is the structure. You know what a structure means now? Ava?
Ava: Things that makes it stable, kind of?
Jean: Stage 2 is the detail. Is that not right?
Mila: I think, the roof is Stage 2.
Jean: Stage 2 is the roof. What is Stage 3?

> Mila, Ava and Ruby (thinking out loud): The door, probably opening and closing. We have lots of stages. I think Stage 4 would be dividing the rooms. That would be the structure isn't it? Probably Stage 4: making the furniture and stuff and adding all the details.
> Jean: Should we say Stage 4 is the furniture?
> Mila: And Stage 5 is the details - like the windows we have to paint. We have 5 stages.
> Jean: All right. that's quite clear stages. It's a good plan.

During this dialogue, the question from the QFT-P "*What will be the five stages of making your product*?" resulted in multiple turns of conversation between Jean and the group. The group thought out the key stages to making their technological outcome out loud and Jean interjected in between, if needed. While talking out loud to each other, the students went from three stages to five stages. Jean also added a little help by suggesting that stage 4 should be furniture. Finally, Jean offered praise "*That is a good plan*". The group had a way forward for making their product. In contrast, when the same question was asked in the online blog, as discussed earlier, Jean did not offer any further dialogue to the student as the students uploaded the blog, and it is not clear whether the students had a clear idea of the stages of making their technological outcome.

To summarise, the questions from QFT-P led to deep and rich dialogue between the teacher and students. The QFT-P questions in an oral dialogue between the teacher and students was more effective in formative assessment than blogs/vlogs that were used as one-sided communication tools. Going beyond initial questioning to a dialogue offers the students the best chance to demonstrate their learning and extend their learning. The teacher can contribute to the dialogue by listening to the student responses and offering feedback. In the discussion chapter, Chapter 7, the finding from this data will be placed in the context of existing literature in classroom dialogue to understand the implications for IFA in TE. The next section will discuss the development of the teacher's technological content knowledge.

5.2.3 Teachers development of technological content knowledge

In the previous study by Fox-Turnbull (2018), teachers found that using TOCF improved their technological knowledge. Considering the finding from the original study, in this study teachers were interviewed periodically about what they were learning by using the QFT-P. Interview data were collated together and triangulated against classroom observation notes and audios. Evidence from both teachers was analysed separately as the length of involvement with both the teachers were vastly different. Examples are offered from instances of the learning about TE.

Jean learning about technology through dialogue

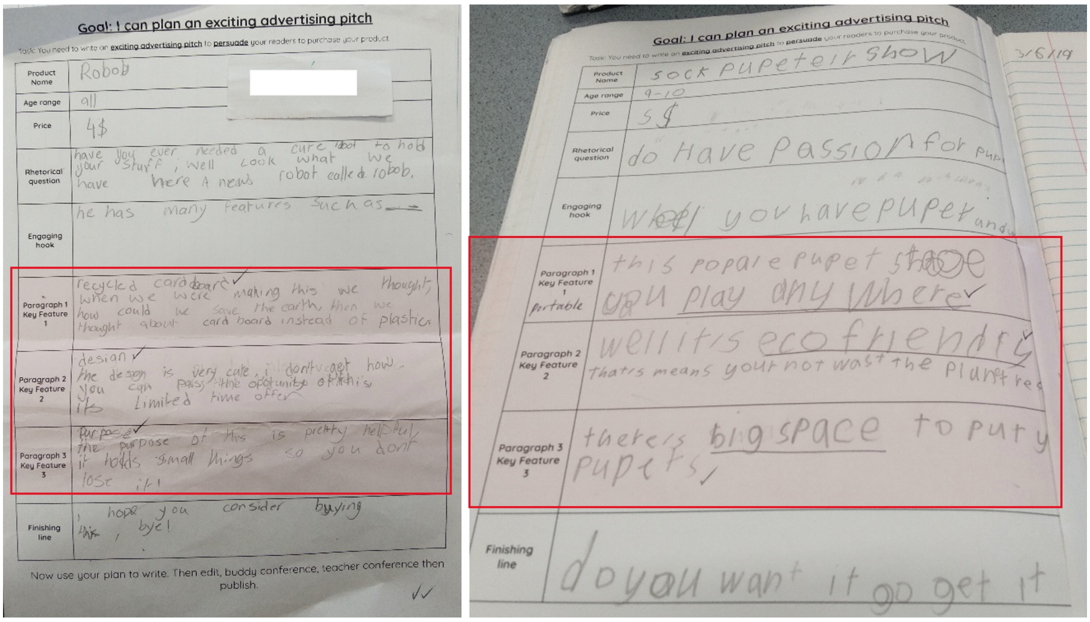
On the first day, Jean mentioned that she read the framework and thought of one question to focus during the class. The question she chose was "*What features do you think would be most important for your customer?*" Jean used the word 'feature' as a rephrase from the word 'attribute' used in the curriculum (see QFT-P in Appendix D). Jean had a ten-minute dialogue with the whole class discussing the word 'feature' and explained why it was important to focus on features while designing a product. In an interview, she commented that the discussion about features "*was the best thing this week. It makes me more aware of knowing that there are these questions that are really good*" (Interview 3 with Jean, lines 16-18). Attributes are a key element of BD component in the strand Technological Practice (TP). Part of the AO at Level 3 of BD is "*Describe the key attributes that enable development and evaluation of an outcome*" (Te Kete Ipurangi, n.d.-b). Jean used the attributes of the students' products to help them develop the product by focusing on the customer's likes and dislikes and adding additional features to the technological outcome like storage space.

Jean asked students to use features to write the market research question; for example, whether the customers wanted four rooms or five rooms in the dollhouse. Jean used the features as starting point for planning the advertising posters. Figure 5.4 shows samples of plans for advertising posters made by the students where the key features students wrote as part of the advertising plan are highlighted. For example, one student said that their puppet stage was spacious and had enough space to put all the puppets. Through the focus on features, Jean had terminology to direct students' attention to the most essential part of the design process - customer needs and wants. As Jean mentioned "*It made me realise that kids need to know what features are*" (Interview 3 with Jean, line 9). Jean discerned those features or attributes were central to the design process through reading a question on QFT-P, aiding an addition to her content knowledge about technology.

In her last interview for this study, Jean stated that reading the framework questions expanded her view of what technology included. She said,

> I think I realised how, broad this [technology] is. Even looking at the framework, and reading those questions and realising that, attachment [of cardboard pieces] is an important part of the design process, and technology as a whole. Whereas before, I would have just thought it's a side thing that you've got to do in order to do the technology, not realising that that's actually part of the technology. And the concepts and the market research is also part of technology. Whereas before, I would have thought, that's not technology that just enables the technology to

Figure 5.4
Images of student plans for advertising posters



happen...the reflection questions that's actually also part of technology, not just something else for the general learning. (Last interview with Jean, lines 283-293)

Jean mentioned that her view of what technology now included many aspects like working with materials, getting stakeholder feedback, brainstorming for ideas, and the reflection process. Design concepts and market research are included in the component BD in strand TP, attaching cardboard pieces to each other is part of component Tp in TK strand and reflection (evaluation) is part of ODE in the TP strand, thus, reading QFT-P improved content knowledge for Jean in TE.

In addition to vocabulary and related technology content knowledge, Jean learned about importance of the behaviours from the QFT-P. In an earlier interview, Jean explained that as a teacher she valued socialisation and reflection but was unsure if she was going against what she should be doing in the classroom: "*All these things that our government tells us are not important because they are not measured and not valued*" (Interview 3 with Jean, lines 36-37). Jean had an impression that the government only valued skills, competencies and knowledge that were measured in formal assessment and for which she needed to record and submit reports. She further explained,

> I feel like as a teacher I am always aware of the outside parties that have a say or want to have a say in education and have an opinion of how I am as a teacher, and I don't care too much about what they think. But the reality is that I do care. (Interview 3 with Jean, lines 40-43).

Through these lines, Jean tried to explain her fear in focussing on skills and competencies that are not measured or tracked by the school or the government. By reading the QFT-P that included socialisation and reflection and which Jean knew was designed by an expert technology educator, she felt reassured of the goals and values that she brought to the classroom.

In a similar vein regarding behaviours, Jean's learning through the framework was evident in her discussion and action on group work. In the first cycle (plastic), Jean asked the class to sit in a circle to discuss the question "*How can working in a team help you make a better product?*". Students who worked alone in plastic cycle defended working independently and students who worked in groups defended working in groups. While listening to the students' discussion, Jean inferred *"It makes me realise that the experience I give them that is going to be their opinion, that is going to be what they think is right"* (Interview 4 with Jean, lines 174-175). However, Jean valued collaboration between students and in line with her belief that interacting with others was an important 21st century skill, Jean began the next unit with talking about the importance of group work (T1-Week1Day1-A1) and asked all students to work in groups for the cardboard cycle.

From the first interview to the last, Jean's confidence in teaching technology increased (Interview 1 with Jean, lines 488-489 and Last interview with Jean, line 639). Jean attributed the increase in her confidence to experience of teaching technology and questioning in the classroom using the QFT-P. In her own words,

> And I think I'm so much more aware of how broad it is, and how much everything can come into it... And so important, because, like physical products or physical things are such a tangible thing for kids, and they enjoy it and they love it. And they are good at it. And it is a really cool way of engaging kids and learning. And yeah, I've really enjoyed it (Last interview with Jean, lines 620-627).

Jean felt an increase in confidence for teaching technology as she had an increased understanding of the scope of TE and reinforcement of her belief that students were more engaged while doing TE.

To summarise, Jean's learning through using QFT-P as an IFA tool in TE increased her content knowledge in TE in two ways - learning and expansion of the content of some of the components of the technology curriculum and reinforcing that the behaviours critical in TE coincide with her personal belief about teaching and the key competencies in the NZC. Jean's learning occurred through reading, using, and reflecting on the QFT-P questions.

Sarah-Jane learning about technology through dialogue

Sarah-Jane was provided with six of the 41 cards of the QFT-P. Sarah-Jane read them frequently and asked many questions from the QFT-P in the classroom. In the initial interview when Sarah-Jane looked at the whole QFT-P, she commented that she would need to teach more technological vocabulary in the classroom.

> It's [reading the framework] actually reminded me about some of the technical language that I should be using, you know, in regard to the technology curriculum. Like stakeholders and maybe even involving *whanau* [family] more and giving the kids feedback, maybe, or however, that problem solving (Interview 2 with Sarah-Jane, lines 347-349).

She further said, "*I could use it to deepen their thinking more around the technology process...*" (Interview 2 with Sarah-Jane, lines 354-355). The questions in the framework, thus, made Sarah-Jane more aware of some aspects of TE that she could strengthen in the students - the vocabulary and thinking about the process. In line with these thoughts, Sarah-Jane started, in limited way, using additional technology vocabulary in the class, for example, the word "components". Sarah-Jane also spoke about the design process briefly in the class in Week 5 and asked students to reflect on who could be the consumer for their water filters which led to a mini-group discussion. For Sarah-Jane, using the QFT-P led to her awareness to teach more technology vocabulary and technology process which she proceeded to begin to incorporate in the classroom.

Both teachers had different learning experiences using the QFT-P. The differences in teachers' learning could depend on factors like teaching experience (Jean had been teaching only for three years and Sarah-Jane for 15 years), familiarity with the technology curriculum (Unlike Jean, Sarah-Jane claimed to be aware of the terminology and the technology curriculum in a limited way), and exposure to the number of cards of QFT-P (Jean was provided with complete QFT-P and Sarah-Jane worked with four cards).

5.2.4 No increase in the workload of the teacher

If the introduction of a new tool increases the already heavy workload of a teacher, it is unlikely to be adopted. Through analysis, it was found that there were two ways that teachers needed to spend time for using the QFT-P - finding time to read the QFT-P and finding time to use the QFT-P in the classroom.

Time spent to read the QFT-P

Both teachers were asked in the initial interview what they might have to change about their classroom processes for them to be able to use the QFT-P. Jean answered that something would have to change because "*Because I wouldn't trust myself to ask a specific question - the right time at the right place which would be really powerful to do that*" (Interview 2 with Jean, lines 271-272). Jean felt that she would be unable to ask questions from the framework as she would not know the correct question to ask for the correct occasion. She also explained that unless she made a change like focusing on a single question to ask every day, or giving the QFT-P to students, or using the question as reflection questions in the online blog/vlog, she could not be sure to ask questions from the framework. Jean did implement two of her ideas in the classroom – focusing on a single question (on feature) and having reflection questions to be answered in the online blog/vlog.

On the other hand, Sarah-Jane said that nothing needed to be changed in her classroom to ask the questions. She said, "*No. I'm a questioner anyway. I need to be more thoughtful in my planning if I were doing this. Or more thoughtful about the questions that I'm asking*" (Interview 2 with Sarah-Jane, lines 367-368). Sarah-Jane explained that she asked a lot of questions anyway in the classroom but to ask specific questions, she would have to do some planning. She further stated that it was difficult to recollect what she asked students since she was constantly thinking on her feet and responding to the student at that moment. Like Jean, Sarah-Jane also wanted to put the questions on the online system so that students could have access to them. She did put the questions on Google slides for the students.

Based on responses from both the teachers, it was clear that there needs to be some change in the existing processes to use the QFT-P but the anticipated changes were not extensive. It must be remembered that Jean was offered the whole QFT-P while Sarah-Jane was offered only six cards at the beginning. The whole QFT-P had 200+ questions and the six cards had around 30 questions. It could be due to the lesser number of questions that Sarah-Jane mentioned that she had read the framework multiple times and that they were in her "*subconscious*" (Interview 5 with Sarah-Jane, line 81). Meanwhile, Jean mentioned that using the QFT-P was difficult for her because she could not keep all the questions in her head and was often at a loss to remember any question from the framework. When she was questioned further on what she could have done to overcome that issue, she confessed that she could have read the framework more, but she did not feel it was a good use of her time. Jean often mentioned in the interviews that her priority was reading, writing and maths and that she focused on those learning areas. Jean frequently mentioned "*But also unfortunately, as teachers, we've got to have stuff to assess*" (Interview 5 with Sarah-Jane, line 133) and:

> It [Reading the framework] wasn't going to help them [students] in their reading, writing, and maths. And even though I guess, it would have but not enough for me

> to put time into it or the evidence for me wasn't clear enough. It wasn't tangible enough for me to see that. Which I guess is just the constant battle of is that worth my time, is it worth the kids' time? So I guess that's the barrier (Last interview with Jean, lines 512-517).

Jean's explanation implied that she had limited time to put effort into technology planning for the students and her priority did not include learning to use the QFT-P better.

Time in the classroom to use the QFT-P

In the classroom, both teachers walked around the classroom and had time to monitor the student work. Multiple interactions between the teacher and student(s) beginning with the questions from QFT-P were analysed. Both the teachers spoke to students in groups and individually during every lesson in the unit. Even if the dialogue started off with the same question, the dialogue with different student(s) was different.

For example, in the second lesson in the water-filter unit, Sarah-Jane asked follow-up questions like "*Why this order (of components)*?", "*What does pebble and sand do*?", "*What does charcoal do*?", "*Why do you need two bottles*?" to five out of seven groups. She did not ask any follow-up questions to two groups and let them proceed with making their product. Of the two groups, one group explained their filter to her with reasons for each layer. However, the other group just explained their basic plan and Sarah-Jane did not ask any follow-up questions. Sarah-Jane later mentioned to me that one of the students in the latter group used to feel helpless and anxious when things got tough for him in the classroom, but he appeared engaged in the water-filter unit. Hence, by not asking additional follow-up questions she wished to avoid any potential for discouragement of the student and she let the group build the plan. Sarah-Jane stated that the reason she did STEAM lessons was to provide access points for students like him and did not wish to discourage him. The feedback to students was tailored to their needs.

In another example, Sarah-Jane spoke to the students who finished the prototype and asked them if the water was clean. When one of the students mentioned that the water tasted bad, Sarah-Jane extended their learning by asking them to think about what else they could do to make sure that the water was clean - not just visually clear. To other groups that did not succeed, Sarah-Jane asked them to redesign their filter. Sarah-Jane's dialogue in the other lessons were in the same vein as the above example - she offered different feedback to different students based on her perception of where the students in the group were in their learning. In fact, both teachers would listen to the students' replies to their questions and tailor the feedback based on their evaluation of the student's learning.

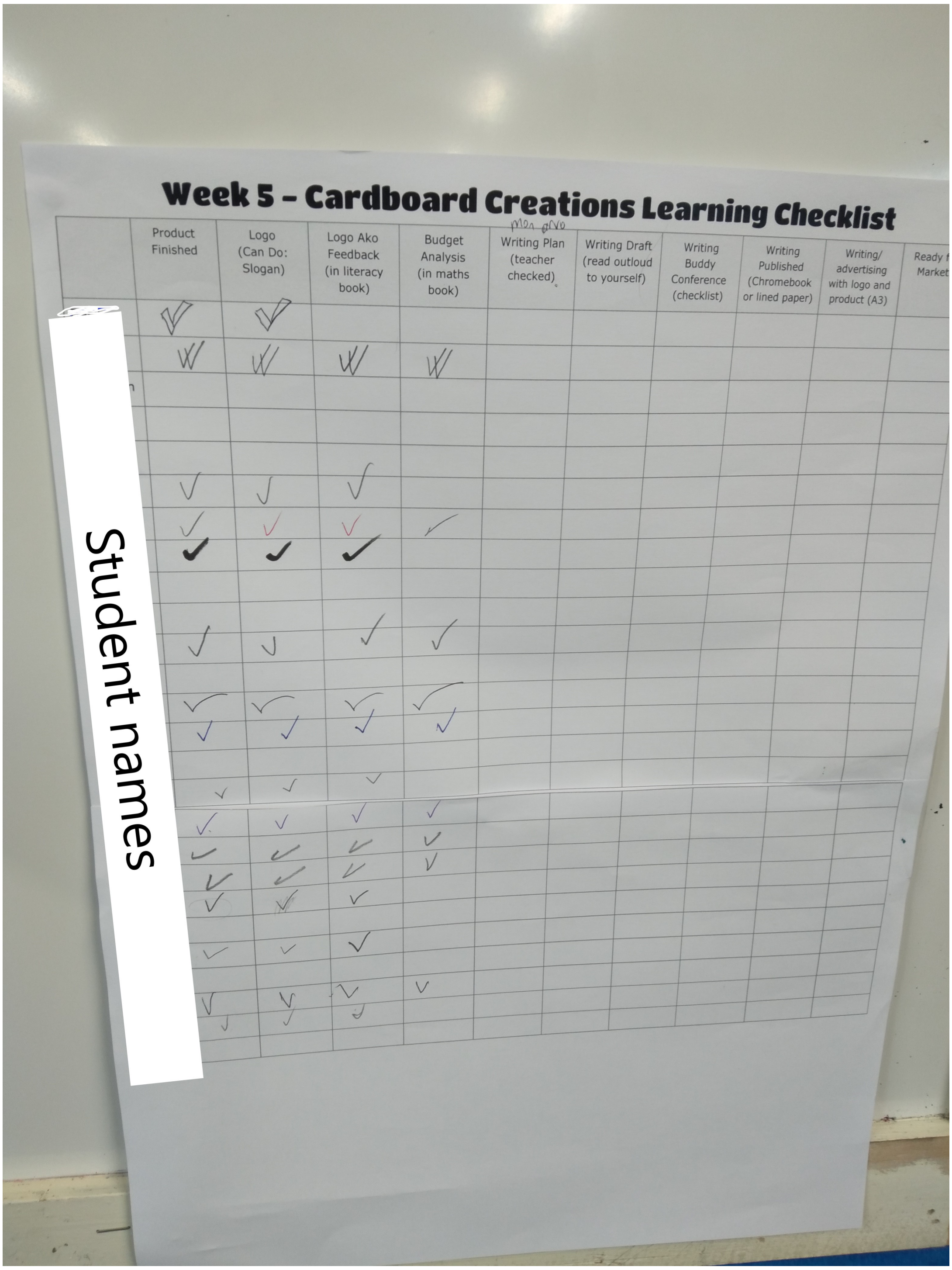
Jean asked some students to be more creative and to others she would provide a concrete idea for a more creative design. For example, Jean asked Nicole and Isla to "pop out of the box" and be more creative (T1-Week3Day1-A1- min 22:50). To Olivia who struggled with concentration, Jean suggested an addition of a feature to make her design more creative by saying "You could add a secret compartment where you hide your treats" (T1-Week3Day1-A1-min 33:29). In another example, Jean started with the question "*From your market research you guys did, what was the most important thing for your customer? What was the most important thing you learnt from the market research*?" (T1-Week2Day4-M1-1 and T1-Week2Day4-M1-2). In dialogue with Ava, Mila and Ruby, Jean discussed the market research the group had undertaken and went over the results with the students. Jean was convinced that the students were following the customer requirements and she moved on to ask the group what their plan to make the product was. Beginning with the same question, Jean's dialogue with Harper and Ria was different - the girls mentioned that the customer wanted storage space, but the girls did not plan to include any storage space. Jean then asked them to challenge themselves and add a compartment with pencil sharpener as well. The discussion then turned to Harper and Ria working out the location of the sharpener and Jean asking them to modify the technical drawing. Noah, Vijay, and Dev gave an unexpected answer to Jean's question - they said that they needed support to make their design. Jean then asked for clarification whether the customers had told them that. With a bit of back and forth, Jean clarified her question to the group and then the group replied that the customers wanted a foosball table rather than a soccer table. Jean continued speaking to the group about what else the customers wanted. In all three instances, Jean's goal was to make sure that all three groups incorporated customer feedback.

The teachers also varied their conversation with students in terms of their frequency of interaction. The two teachers monitored and checked on some students more frequently than the others. For example, Jean monitored Olivia and four other students in every lesson. Olivia, who struggled with social difficulties and attention related difficulties, Jean monitored frequently in the class and set goals for her to complete in every lesson. For the rest of the students, Jean used a checklist in the classroom (see Figure 5.5) to keep track of student progress. Jean provided additional support during making stages to Andy as he could not attach arms and head to his robot (T1-Week4day4-A1). Jean seemed to have more frequent conversations with students when she perceived they needed additional support in their learning or to keep students on task.

Sarah-Jane gave time limits to certain groups and asked questions if she felt they had not participated. There are multiple examples from each lesson evidenced through the classroom audios about Sarah-Jane following up to make sure everyone on the team

Figure 5.5

Checklist for students to track their progress in the week at Athena



contributed. For example, in the third lesson, she asked one of the groups, "*So everyone knows what you are doing? It does not matter who I ask the question to because all of you know?*" (T2-Week3-min 11:50). She would then ask questions to different students in the group and if anyone did not answer, she would send back the whole group to discuss and follow-up with them later. Sarah-Jane also gave students more time to discuss and research in case they were unable to answer her questions. For example, in lesson 2, Sarah-Jane gave Mia and group some time to think and discuss and spoke to them twice before she gave them permission to make construct their design, but she gave permission for Aisha and group to make after speaking to them once. Hence, Sarah-Jane spoke more frequently to some students to get them to fulfil the lesson objectives.

The findings above suggest that in dialogue with the students, teachers were able to provide the required support organically, with impromptu comments, and without having to plan the interactions in advance. The teachers' dialogue with students differs in two ways - frequency and feedback. Teachers offered different feedback based on their perception of where the students were with their learning. Teachers determined the frequency of conversation with students for the purpose of providing additional support for struggling students, ensuring everyone contributed to a group and ensuring that all students met the lesson objectives. To better facilitate this, the usability of the framework was considered.

5.2.5 User friendliness and flexibility

The main attribute that the teachers commented on and asked for changes for was the user-friendliness of the QFT-P. The teachers found it difficult to use it in the classroom and felt overwhelmed with the number of questions despite knowing that they needed to use only 1-2 sheets at a time. Hence, to improve user-friendliness of the QFT-P, it was modified from A4 sheets to smaller sized cards. Sarah-Jane seemed comfortable with being offered a few cards at a time. It also gave her an opportunity to read the cards several time, as she confirmed when interviewed. She said "And I have read them more than once now. So that's probably subconsciously here anyway" (Interview 5 with Sarah-Jane, lines 80-81)

In terms of flexibility, QFT-P is a paper-based tool and cannot be automatically updated. In this study, due to the relatively short period of involvement in the classroom, there was no evidence of any of the teachers modifying/ extending the QFT-P as per their need. Although teachers can modify it for their use, QFT-P only has limited flexibility as it is in a hard-copy format.

Flexibility also implies that the QFT-P needs to be compatible with other processes/ tools in the classroom. Being a paper-based tool, QFT-P did not interfere with any computer technology in the classroom. Jean mentioned that the questions in the QFT-P were "*really good*" and "*..it will help to overcome the one where I don't know a good question. So even if I've got that to refer to twice a day, I think that could be helpful*" (Interview 4 with Jean, lines 290-292). Jean indicated that the QFT-P will fill a gap for her by providing good questions. Sarah-Jane mentioned that "*I could use to even deepen their thinking more around the process, the technology process*" (Interview 2 with Sarah-Jane, line 353) explaining that the questions from the QFT-P would help her in the classroom by getting the students to think deeper about the technology process. Through the feedback that both teachers offered on the QFT-P, there is evidence that the teachers found the QFT-P to be an enhancer rather than a hindrance.

5.2.6 Near zero cost for the QFT-P

The cost of any tool is not only the development cost of the tool, but also involves cost of distribution, licensing, updates, maintenance, and training. QFT-P is developed by university researchers as part of their research work. Hence, there is currently no cost involved in development and licensing. The QFT-P is a paper-based tool and needs to be updated by the teachers as per their need and convenience but keeping the basic TE curriculum and classroom goals in mind. Hence, there is no cost of maintenance or updates. There is some cost involved in printing and laminating the cards. However, considering most schools have printers and laminators, these costs are negligible.

With regards to cost related to training, the intention in the development of QFT-P was for teachers to be able to use the tool without much training. The data from teacher interviews and observation notes were analysed to find evidence for whether teachers could use the tool without training. Both teachers mentioned in the earlier interviews that they had no formal training or formal studies in technology education, and that their knowledge was self-taught or from their past experiences of doing design studies or from colleagues and peers over the internet or in the school (Interview 1 with Jean and Interview 1 with Sarah-Jane). The teachers did not seem to be in correspondence/ conversation specifically with technology teachers or using teaching resources in TE such as the Technology online website (as stated in the interviews). The teachers lacked exposure to TE and it is not surprising that the content knowledge of both the teachers in technology education was limited. Lack of content knowledge caused limitations in the way the teachers used the QFT-P. Teachers' lack of content knowledge was also observed in the classroom observations and confirmed through the teachers' answers in the interviews.

The specific gaps in their knowledge were explored through the classroom observation notes and the classroom audios. Jean confessed that she was not able to recollect the questions from QFT-P and did not know a relevant question to ask.

> So, for me to find a question, that fits a situation, I can't go and see a kid and ask 'Your bottle isn't working?' let's just stay there for two minutes while I find an effective question to ask you about it. It would have been awkward and not natural. So that I found tricky. (Last interview with Jean, lines 456-459).

Although Jean mentioned that this problem could be solved by reading the framework every day and thus, increasing her familiarity with the many types of questions she could ask, the issue regarding not being able to recollect any questions could also be resulting from a lack of content knowledge.

The gaps in content knowledge for Jean were not knowing technology terminology or not applying known knowledge in the lessons with the students. For example, Jean had a lesson with a group of students on reading "The cardboard cathedral" that explained the process of designing the cardboard cathedral in Christchurch. The reading had terminology like "prototyping", "modelling", "design brief", and "attributes". Jean did not seem to know the difference between model and prototype and asked me to explain it to the class. She also did not know 2D drawings could be models and this gap in knowledge related to the component TM in the technology NZC. While she explained to the class the importance of testing products, she did not ask the students to test theirs - even in simple ways like putting pens inside the pen holder. She spoke to only two student groups about stability and sturdiness of the design and did not ask any group to test the stability of the structure in any way. The students did not have an opportunity to fulfil part of the AO in ODE that related to evaluation of technological outcomes.

In every unit, Jean had readings and activities on the material being used in that unit. In the plastic unit, the students read about how plastic causes pollution and in the cardboard unit, Jean did an activity about what cardboard is and asked students to find some facts about cardboard. The knowledge about materials is part of the component Technological products but in the context of this classroom activity could also be part of the component CTO. A limited part of the unit focussed explicitly on aspects of these two strands, through discussion of how cardboard is made and seeing examples of different products made from plastic and cardboard. However, the learning objectives fell short of the relevant AO's by not fully making the knowledge explicit. For example, Level 3 AO of CTO is "*Understand that technological outcomes are recognisable as fit for purpose by the relationship between their physical and functional natures*"

(Te Kete Ipurangi, n.d.-b). However, the functional nature of plastic and cardboard were not discussed, and the physical nature was discussed in a limited way. Similarly, in Level 3 AO of Tp is *"Understand the relationship between the materials used and their performance properties in technological products"* (Te Kete Ipurangi, n.d.-b), the performance properties (with the exception of physical properties) in relation to a specific product were not discussed.

To summarise, Jean had gaps in her knowledge on technology terminology and at least some gaps in the component TM. While she had knowledge on other aspects of TE, she was unable to translate her technology knowledge in the classroom at least in evaluation of products as part of ODE.

Due to the shorter time spent observing in Sarah-Jane's class, no gaps in technology terminology were observed in her classroom. Field notes indicate that Sarah-Jane was aware of terms like prototype, and components through her use of these terms in the classroom but was not heard using other terminology. There were other opportunities for Sarah-Jane to have used words like "brief", "technological outcomes", "attributes", "technology", "models/ functional models", "2D drawings", "evaluation", "fit for purpose", and "performance properties".

Sarah-Jane spoke to only two out of the eight groups about the layers in the ground being a natural water filter. Mentioning a natural water filter in the ground in comparison to the water-filter being designed in the class could have been a good opportunity to have a talk about how the water filter they design is technology while the one in the ground is naturally occurring. This differentiation would fulfil the AO for Level 3 of CT "*Understand how society and environments impact on and are influenced by technology in historical and contemporary contexts and that technological knowledge is validated by successful function*" (Te Kete Ipurangi, n.d.-b). Sarah-Jane also did not encourage students to develop their 2D models - she accepted rough sketches in the plans contrary to the technology IoP that states "*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*" (Te Kete Ipurangi, n.d.-b) for Level 3 of ODE.

Besides the lack of content knowledge evident in the data, there was a curious thing evident in the gap between knowledge and practice of the teachers. As mentioned already, knowledge of the technology terminology did not translate into the classroom for Sarah-Jane. In Jean's case, her knowledge about evaluation of products did not translate into the classroom as well. Another curious example in Jean's case was evident when she mentioned multiple times in the initial interview that she was not familiar with technology education but knew the design process. However, in one of the interviews where she was evaluating the student products, Jean exhibited considerable knowledge about important attributes for products. For example, regarding design of a bird feeder by a specific student, Jean said, "*I would talk to him about the storage of the bird seed... So I think I would get him to start thinking about what is the purpose of it?....So how much good seed can it hold?*" (Interview 5 with Jean, lines 80-85)

It can be seen above that Jean indicated that one of the attributes of a bird feeder is the storage space for seeds and is part of the functional attribute of the bird feeder. She further talked about rain, indicating that protection from rain is another important attribute that Jean recognised.

> I will get him maybe to think about, what of rain coming from this side? You know, is it going to get into the seed. Maybe start stretching him so that he can think about created an awning or something (Interview 5 with Jean, lines 89-91)

She had already mentioned earlier in the interview about attributes like a method to hang the bird feeder and a perch for birds. However, while the student was making the product, Jean had none of these conversations with the student. Jean was also aware of the need to test products as evidenced by her conversation in the interview where she explained,

> If it's going to be a bird feeder, or a cat feeder, let's put some... what can we use in the classroom that we can test it out and put it in there and see, is it all just going to flood out? Is it going to be a good flow? See what it's actually going to work (Interview 5 with Jean, lines 108-110).

When asked why Jean did not have those conversations in the classroom, Jean said, "*But for me, if I could sit down and talk with the kid for five minutes and if I was told... say what you've just done, then I'm forced to think about that. That kind of thing doesn't come naturally*" (Interview 5 with Jean, lines 136-139). Thus, Jean indicated that one of the reasons why she did not have the dialogue with the student to extend student knowledge about attributes that forms part of the component BD, is that it was not natural for her to think on her feet about technology in the classroom setting. The gap between knowledge and practice of the teachers will be discussed in the next chapter.

Through genuine lack of content knowledge or being unable to translate the content knowledge in the classroom and especially through their unfamiliarity with the TE curriculum document led to missed opportunities in student learning. Students could have been given the opportunity through questioning and/or dialogue/conversation to extend their learning and prepare for the next stage in technology education curriculum progressions. The lack of content knowledge formed a barrier for use of the QFT-P in the classroom. Teachers need professional development to fill the gap in the content knowledge and hence, future use of QFT-P cannot be said to have near zero cost.

The final attribute of the QFT-P that needs to be evaluated is the positive impact of student learning. However, as mentioned before, the data sources and analysis methods for evidence related to student learning is different from the attributes mentioned in this chapter. Hence, the student learning attribute will be discussed in the next chapter.

5.3 Chapter summary

The findings chapter on IFA in TE began with the teacher beliefs and findings from context of the units that formed the main data source for the findings presented in the chapter. Data were analysed to present evidence on the development of QFT-P and the purpose and attributes of the QFT-P.

There is evidence to support use of QFT-P as formative assessment tool. Teachers used the QFT-P as formative assessment and could recognise student learning and extend it through providing feedback. The feedback categories observed in this study were teacher asking for clarification, developing student thinking, redirecting student thinking, reinforcing learning, providing praise and encouragement, and providing support for the next step.

QFT-P when used in oral dialogue, led to longer dialogue between the teacher and the students. However, when students were given the questions to answer amongst themselves in blog or vlog form, there was no opportunity for dialogue. Teachers learnt about TE from using the QFT-P and the resulting dialogue from the students. Teachers learnt about content of TE as well as the behaviours essential in TE. However, despite evidence for learning about content of TE on using the QFT-P, there was evidence of missed opportunities related to the teachers' limited content knowledge in technology. To bridge the gap in content knowledge, professional development may need to be provided for teachers, increasing the cost of using the QFT-P. On the other hand, teachers did not need to change the existing classroom processes too much to be able to use QFT-P. The QFT-P, if offered few cards at a time, has evidence of being user-friendly. Teachers needed to invest some time in reading the cards of QFT-P to increase their familiarity with it and be able to make relevant changes in the future, if needed. While using the QFT-P in the classroom, teachers varied their dialogue with students based on the feedback and frequency. With some students, they either changed the nature of the feedback or increased their frequency of feedback.

This chapter presented the findings for IFA in TE as analysed from the data from the two classrooms. The implications of the findings need to be explored further and contextualised based on existing literature. The implication of importance of dialogue rather than questions, the patterns of dialogue in TE especially can have a significant impact on the way TE lessons are executed in the classroom. This chapter focussed on the teachers - their questions, their dialogue, and their learning. The next chapter approaches the data from the student perspective. Student voice represented through their work and their dialogue with teachers was analysed to identify their learning in a TE classroom.

Chapter 6

Student learning

> I believe that the school must represent present life - life as real and vital to the child as that which he [sic] carries on in the home, in the neighborhood, or on the play-ground (Dewey, 1897, Article 2).

The last attribute that was desired when designing the QFT-P was for the resulting dialogue to have a positive outcome on student learning. Student data were analysed from the photographs of student work, their reflection videos and their conversation with the teacher. A modified item-file (Alton-Lee, 1984) was created for each student group. The modified item-files were analysed inductively using aspects of thematic analysis to identify the learning that the students exhibited. Since the dialogues analysed for the student work began with questions from the QFT-P, the findings also offer evidence for student learning through dialogue.

The data for findings was collected from the cardboard unit at Athena and the water-filter unit at Minerva. In rare cases, where appropriate, some data from the plastic and fabric unit at Athena and the *Hinaki* (eel-trap) unit at Minerva are used to strengthen the findings - such inclusions have been noted. All student work, and all teaching resources were photographed. Student work encompasses their technological outcome, drawings, writings, conversations in the classroom and their answers in group discussions or whole class discussions. At Athena, the first week of the cardboard cycle was dedicated to narrowing down to one idea, the second week focused on making the technological outcome, and in the third week, students made the advertising poster for their technological outcome. Appendix M shows the different outputs the students produced over the three weeks. Appendix K shows the different groups of students and the technological outcome they made for the cardboard unit. At Minerva, Sarah-Jane had provided a Google slides template for students to fill up. The template is available in Appendix J for reference. Appendix L shows the different student groups on different days as Sarah-Jane made some minor changes in the groups in Lesson 3 because two new students joined the class midway through the unit.

The student learning could be classified in two categories: those related to the technology curriculum and those related to teacher's priority objectives for the class. As the students engaged in dialogue with the teacher, data indicated that they followed the suggestions made in the dialogue only in some instances and these are discussed in the final section of the chapter. Thus, this chapter is presented in three sections – dialogue and TE curriculum objectives, dialogue and teacher's priority objectives, and dialogue and student's uptake of feedback.

6.1 Dialogue and technology curriculum objectives

This section provides a detailed explanation of the learning demonstrated by the students at Athena and Minerva in relation to the TE curriculum objectives. The TE objectives are discussed under the sub-sections of student learning in deciding what to make, about materials, importance of the consumer, technological modelling, development and evaluation of technological outcome, and design and visual communication. Each sub-section will present what the teacher taught first, the AO from NZC the lesson matched with, and then student evidence that they learnt what was taught.

6.1.1 Student learning to decide what to make

The first step in designing and making a technological outcome is to decide what to make. In primary schools, students are usually given an issue within a context and target consumer group before students make a technological outcome (Ministry of Education, 2018b). From the point the design brief is given to students, they must make multiple decisions based on consumer needs, material availability, and working around other constraints before they can start planning the technological outcome (ibid). This section will discuss findings regarding what students learned about the way to reach a decision on the final technological outcome. The section is divided into students' learning to analyse the design brief, to do market research, and to finalise a list of attributes.

Learning to analyse the design brief

Both teachers introduced a design brief for the unit in the first lesson of the unit. Students then continue to develop the brief through the initial stages of their technology practice. Having a design brief for the unit fulfils the AO for Level 4 in the strand TP and component BD in the NZC "*Justify the nature of an intended outcome in relation to the need or opportunity*" (Te Kete Ipurangi, n.d.-b). Based on IoP, the relevant student

Figure 6.1
Design brief on the soft board at Athena

indicator for Level 4, BD are "*identify a need or opportunity from the given context and issue*".

Jean discussed the brief for the unit "*Design and build a product to sell at a market, using recycled cardboard*" which was additionally posted in the classroom soft board (see Figure 6.1) for the duration of the term. She further added that the technological outcome needed to have a use beyond decoration. Given a context and issue, students came up with an idea for technological outcome.

Since every student at Athena came up with an idea of an appropriate technological outcome, they demonstrated that they met the Level 4 student indicators for BD in relation to identifying a need or opportunity. Jean reinforced the brief for the unit several times in the classroom. In at least eight different instances, the evidence showed that she asked a student/group about the purpose of their technological outcome. Their answers demonstrated that they understood the brief. In the first two days of the cardboard cycle, if Jean heard answers that were vague, or did not meet the brief, she asked them to rethink their technological outcome idea. Dialogue, thus, helped Jean ensure that every student understood the design brief for the unit. Students at Athena demonstrated that they knew why the outcome needed to be developed in their advertising poster when they mentioned why their technological outcome was going to be useful to their consumer. For example, Brooke and Emily had these lines in the poster "*Are you tired of playing with your boring old toys? I have the answer to your unbelievably annoying problem...*" indicating that the purpose of their product was to provide a new toy. Sophie and Lucas had these lines in their poster "*Have you ever needed a cute robot to hold your stuff... Astonishingly this robob is very helpful...because it can hold small things that you will always lose...*". Through these lines Lucas and Sophie indicated that the purpose of their robot called "*Robob*" was as a stationary holder. Every student produced an advertising poster.

Further at Athena, with 11 students (of the total 26 students) who read an article called "*The cardboard cathedral*" about a cathedral constructed in Christchurch, NZ, Jean discussed what the word "design brief" meant and asked the students what the "design brief" for the unit was. The students replied with the design brief for the unit. At least for those 11 students, there was a metacognitive learning of what they were doing in the classroom and an experience of authentic learning since they learnt that "design brief" is the first step for real-life projects like the designing of the cardboard cathedral. In addition, technology terminology "design brief" was introduced to their vocabulary.

Sarah-Jane introduced water filters in the first lesson and got students to think about why water filters are needed by showing them a news clip that discussed the effect of water pollution in a town in NZ. Sarah-Jane identified a technological outcome that could solve a problem. Students then designed a water-filter based on the materials provided. At Minerva, students could demonstrate that they understood the importance of water-filter in the first lesson where they discussed with the teacher about importance of filtered water and water-filter in a whole-class discussion. Thus, students at Athena and Minerva demonstrated that they met the Level 4 student indicator for BD.

Learning about market research

At Athena, in a class discussion about market research, Jean discussed the importance of doing market research and using features as the basis for market research questions. She wrote down a list of features that students could use that was generated from the class discussion (see Figure 6.2). Jean attempted to teach the AO related to BD in the strand TP. The relevant student indicators for Level 4 (Te Kete Ipurangi, n.d.-b) are *"establish the key attributes for an outcome informed by stakeholder considerations"*.

Some students raised the question about ignoring the market research output and going ahead with their own ideas. "*What if they don't want to buy it but we make it anyway?*" (T1-Week3Day2-M3-min 27:00-34:35) is one of the questions that a student raised in a whole-class discussion. The class discussion in relation to this question resulted in how it would not sell, and you would not make any profit and you could go bankrupt. Jean gave some more real-life examples such as referencing daily-use products like cell phones to drive home the point that listening to market research is important. By writing market research questions and conducting survey among the target customer group (other students in the school aged 10-11 years old), the students established some of the key attributes informed by stakeholder considerations.

Four groups out of 12 groups answered the reflection question "*From your market research results, what will you change about your design?*" which offers an indication of whether students learned that the changes suggested by customers had to be incorporated. Dev, Ava, Sophie, Bao mentioned that they changed their design to accommodate customer changes. Sophie's reply "*Instead of it being light grey, it will be dark grey and instead of moveable limbs we are going to make a storage space*" (T1-Studentreflection-Week1-Sophie) is a typical example of what the students mentioned addressing aspects of visual appeal and usefulness. Three groups changed their technological outcome completely despite having done market research on a different technological outcome. The evidence indicates that the majority of students in Jean's class at Athena were unclear about the importance of market research.

Learning to finalise a list of attributes

The recognition and enumerating key attributes relate to the AO at Level 3 of the component BD that had the student indicator "*describe attributes for the outcome and identify those which are key for the development and evaluation of an outcome*" (Te Kete Ipurangi, n.d.-b). In relation to the attributes of their technological outcomes, students at Athena offered a list of size, shape, and colour as the main attributes. However, there were many other attributes that the students failed to recognise, for example, only one group mentioned stability of the design in any of the recorded interactions. Students, thus, showed beginner skills against this outcome. From the analysis of the interactions in the classroom, Jean displayed limited knowledge about attributes which could have in-turn led to students' limited knowledge about attributes.

Figure 6.2

Features collated by the classroom at Athena for recycled cardboard outcome

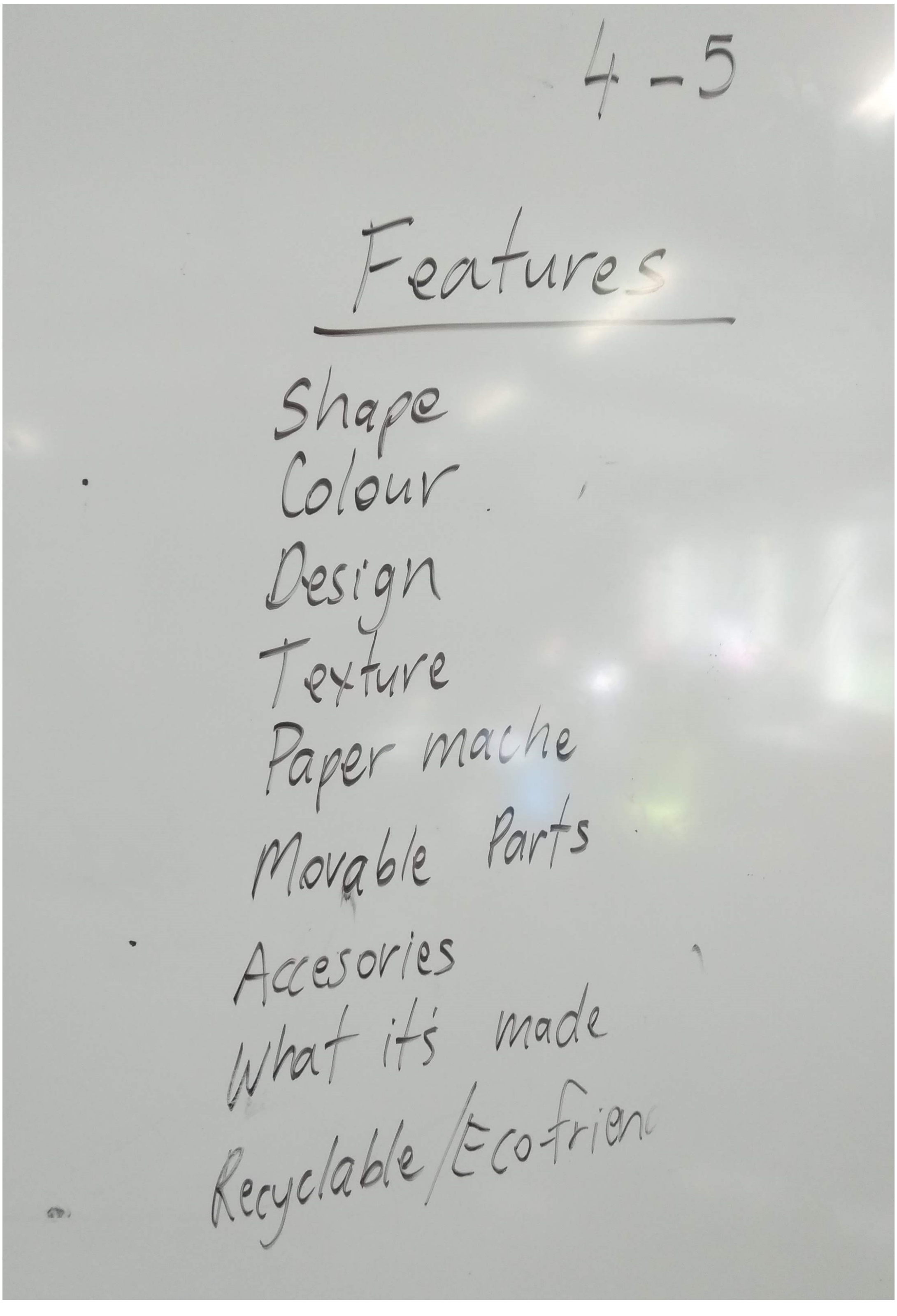
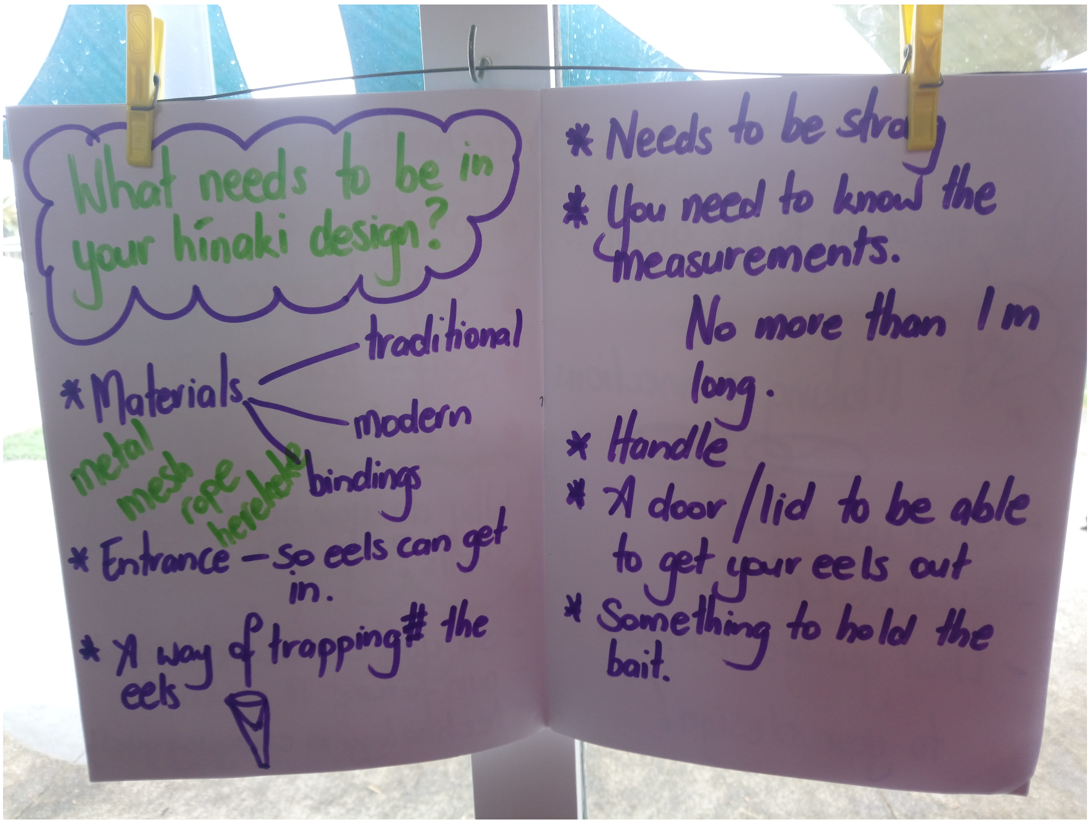


Figure 6.3
Attribute list at Minerva for Hinaki



At Minerva, the students did not have a target consumer group and hence their list of attributes was short - students had a brief and restricted list of materials that they could use for making their prototype. The list of attributes discussed in the classroom was short and unwritten, but students demonstrated that they could make their prototype meeting the short list of attributes. All but one group got clean water from their water-filter prototype providing evidence that they met the list of attributes. In a previous unit on *Hinaki* (eel-trap), Sarah-Jane had co-constructed a list of attributes with the students (see Figure 6.3). However, there is no evidence that students could independently make a list of attributes for developing a technological outcome - which does not indicate that they cannot do it. More than two units need to be observed for evidence. The next technology objective discussed is the learning about materials.

6.1.2 Student learning about materials

The learning about materials fulfils the AO "*Understand that there is a relationship between a material used and its performance properties in a technological product*" at Level 2 of strand TK and component Tp. The student indicators for this AO in the IoP are that students can: "*describe the performance properties of a range of materials and use these to suggest things the materials could be used for*", "*describe feasible ways of*

Figure 6.4

Techniques to work with different materials posted by Jean

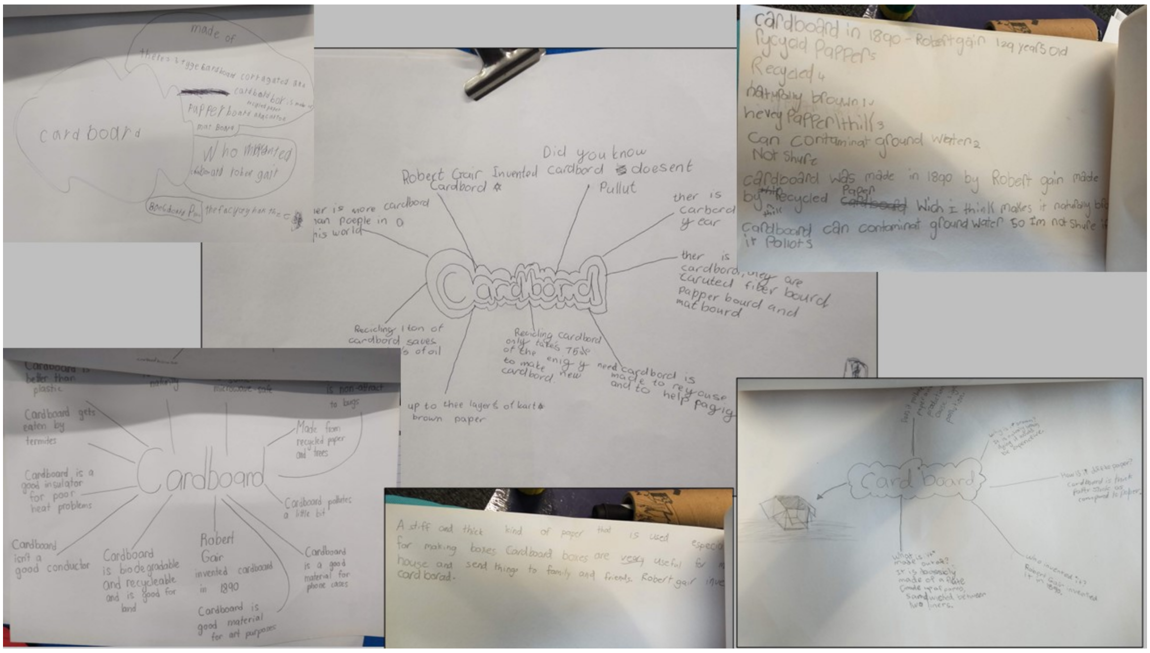
manipulating a range of materials", and "*suggest why the materials used in particular technological products were selected*" (Te Kete Ipurangi, n.d.-b).

Jean had an activity in the beginning of the unit where she discussed about cardboard as a technology and a material with the whole class. In the previous unit on plastics, Jean had discussed about plastic pollution and the unit after, on fabric, she discussed how cotton and wool are made. Thus, the aim for Jean was to use the same design brief with different materials so that students can learn about different materials and learn about manipulating different materials. Jean discussed with students the different attachment techniques that could be used for cardboard and had students practice these attachment techniques with small pieces of cardboard. Later, she helped students use the attachment techniques if they struggled with attaching two pieces of cardboard. She also taught students different sewing techniques in fabric unit and taught them to drill plastic bottles in plastic unit. All these techniques of working with different materials was posted in the soft board through the unit so that students could refer to it and use it any time. See Figure 6.4 for the photographs of these techniques posted on the soft board.

At Athena, Jean had a whole class discussion about cardboard, and the students made mind-maps about cardboard where they recorded how cardboard was made, who invented it and its environmental impact. The mind-maps providing evidence of

Figure 6.5

Collage of mind maps about cardboard made by students at Athena



student learning about cardboard can be seen in Figure 6.5 which shows a collage of the students' mind maps. Students noted many different facts about cardboard including how it is made and its uses. Thus, a whole class dialogue gave Jean an opportunity to let students demonstrate their technological knowledge about cardboard as a material, how it is made, and its properties.

By working with different materials and making different, appropriate technological outcomes in the three units, Jean's students demonstrated that they could manipulate different materials and identify what the materials were used for. However, since there was no activity/dialogue on why certain materials are appropriate for certain technological outcomes, there is no evidence on student learning for this indicator.

In the cardboard unit, some students used attachment techniques of cardboard in making their technological outcome as well as dialogue between Jean and some students. In their answers on the reflection videos (T1-Studentreflection-Week3), students mentioned that they found gluing and painting on cardboard hard thus demonstrating the challenges with manipulating cardboard. For example, Leo mentioned that cutting a very hard cardboard box was difficult and their technological outcome fell apart in the end. Nicole said that folding cardboard was difficult so she chose a cereal box since it had thinner cardboard. Andy mentioned how the head of his robot was so heavy that he could not balance it on the body, Dev mentioned how attaching the skewers to each other with hot glue was difficult. Gluing proved additionally difficult since there was limited amount of glue sticks and hot glue guns in the class. Most students in the class mentioned manipulating of cardboard difficult in their specific case. Technological knowledge can be imparted through practice and giving students an opportunity to reflect on their practice. Students indicated through their replies to the QFT-P reflection questions that their learning about manipulating cardboard was far more complex due to hands-on practice for an authentic purpose. The complexity with cutting, joining, attaching, and manipulating different bits of cardboard provided an authentic experience for the students.

At Minerva, Sarah-Jane's focus was on the components that were used to make the water-filter and how they worked together to filter water. She spent one full and two half lessons having dialogue with students about materials as well as asking students to research about materials. Before students made the two prototypes, Sarah-Jane had dialogue with all the student groups and asked them questions about the components of the water-filter. At Minerva, six out of the seven groups, there is evidence through dialogue with the teacher showed some understanding of the different components that made up the water-filter. One typical dialogue between Sarah-Jane and a student group is presented below (T2-Week 2-min 18:57-20:41).

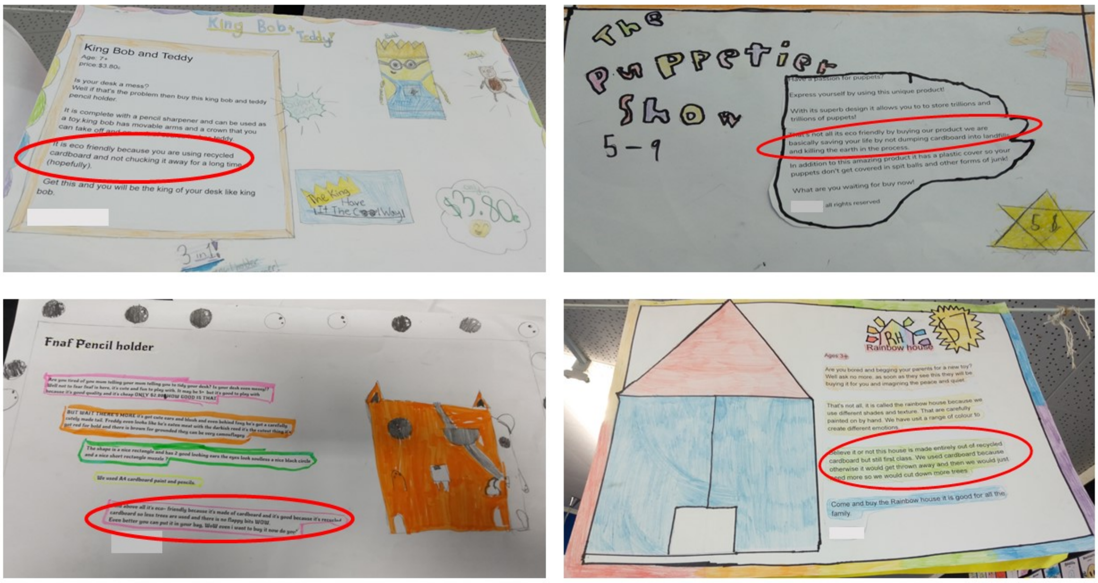
> Sarah-Jane: What are you doing?
> Ana and group: We are going to put sand and then pebbles. Little bit of cloth and ...pebbles will stop leaves and all from getting in. We are going to have a little hole so that clean water can come through.
> Sarah-Jane: I am going to let you guys make this now.

The dialogue shows that Sarah-Jane asked questions about the components of the water-filter and why they worked which was explained by Ana and her group. Sarah-Jane recognised the student learning from their responses and she let them proceed to the next step of making the prototype. With some groups, Sarah-Jane had to ask more pointed questions about the layers and while making the second prototype, she asked more questions about role of charcoal and how it purified the water. Students' replies suggested that they had some understanding of the role of the different components. Students experimented with different components of the water-filter and with different thickness of each material in their two prototypes. Analysis of the student plans and outcomes indicated that they understood that different components helped with water cleanliness.

At Athena, in the specific context of the unit, exploration of the different materials could also partially fulfil the AO "*Understand how society and environments impact on and are influenced by technology...*" (Te Kete Ipurangi, n.d.-b) in Level 3 of the strand

Figure 6.6

Collage of student posters showing eco-friendly feature of their product



NT, component CT. In the IoP, part of the explanation for the AO is "*guide students to determine the impacts different technologies have had on society and/or the environment over time*". The relevant student indicator for Level 3, NT/CT is "*describe how societal and/or environmental issues can influence what people decided to make, how they would undertake planning, the selection of resources, and how they would make and test an outcome*" (Te Kete Ipurangi, n.d.-b). In discussing the pollution created by plastic and the environmental effects of recycling plastic and cardboard in their advertising posters (Figure 6.6) students demonstrated their understanding of the impact of society and technology on each other. All students had comments about the importance of recycling and the effects of plastic pollution in the posters indicating that they learnt about the effect of technology on the environment.

Another AO is partially described in IoP as "*provide students with a range of technological outcomes with unknown functions to explore and guide them to make informed suggestions regarding who might use them and the possible function they could perform, as based on an exploration and analysis of their physical nature*" in Level 3 of the strand NT, component CTO (Te Kete Ipurangi, n.d.-b). The relevant student indicator for Level 3, NT/ CTO is "*describe possible users and functions of a technological outcome based on clues provided by its physical attributes*" (Te Kete Ipurangi, n.d.-b). In working with different materials which are technology themselves, students demonstrated that, in this case, they could identify the purpose of a technology based on the study of their physical properties. Thus, the evidence indicated that the lessons at Athena partially fulfilled other AOs across other strands. I will now consider the technology objective related to consumer's input.

6.1.3 Student learning about the importance of consumer in design process

The AO "*Understand that technological outcomes can be interpreted in terms of how they might be used and by whom and that each has a proper function as well as possible alternative functions*" in Level 4 for component CTO and strand NT (Te Kete Ipurangi, n.d.-b). The relevant student indicator for this Level in the IoP is "*explain possible physical and functional attributes for a technological outcome when provided with intended user/s, a purpose, and relevant social, cultural and environmental details to work within*" (Te Kete Ipurangi, n.d.-b).

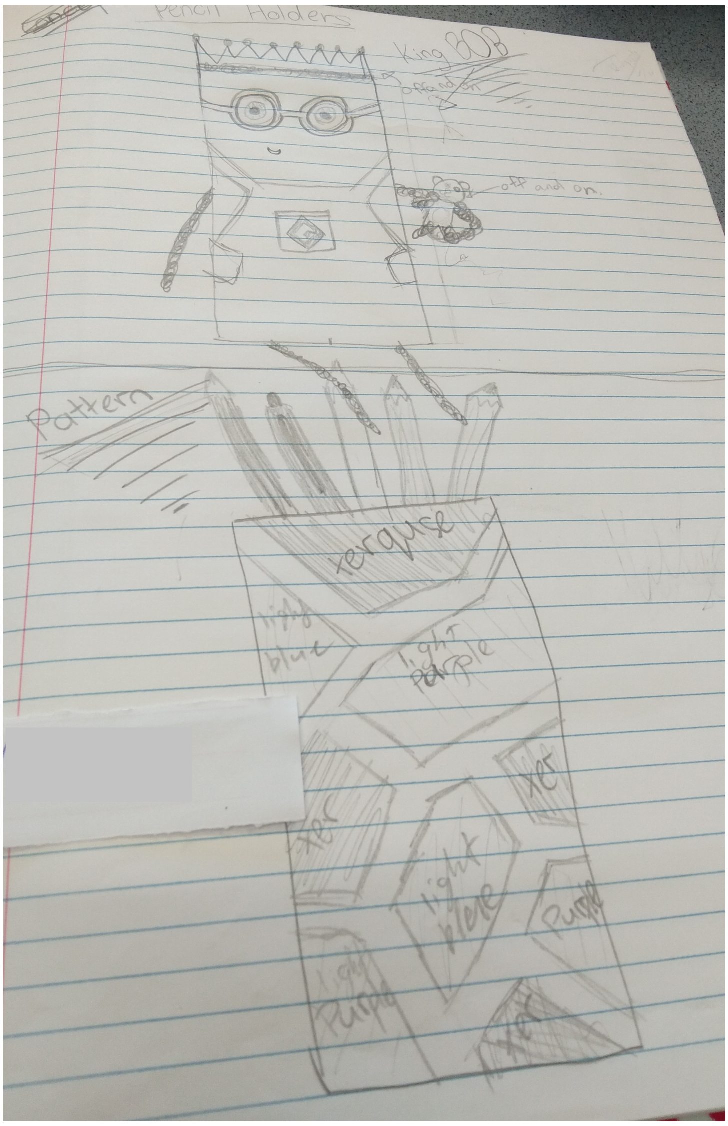
Jean stated, "*Realising that it's not about, when you make products, it's about your consumer*" (Interview 1 with Jean, lines 317-318) when asked to comment on what the students had learnt during the cardboard unit. Students demonstrated this learning in their answer to the reflection question at the end of Week 2 "*How would you change your design if you were making it for 3–4-year-olds?*". 16 out of 22 students answered this question and each one suggested an appropriate way to change the technological outcome for the target age group (T1-Studentreflection-cardboardWeek2). For example, Harper and Ria replied that they would make their technological outcome bigger and remove the sharpener so that it does not hurt the child. Ruby and Mila said that they would not change the doll house but would make the things inside bigger while Andy and Nicole said they would make funny faces instead of scary faces. Others mentioned changing the colours of their technological outcome. The replies provide evidence that Jean was correct in her assessment that students learnt that designing a technological outcome was primarily about the consumer and not their own personal taste.

6.1.4 Student learning in Technological Modelling

In making the drawing students fulfilled part of the AO "*Trial and evaluate these against key attributes to select*" in Level 3, for the strand TP and component ODE (Te Kete Ipurangi, n.d.-b). The student indicators that students demonstrated for Level 3 of ODE is "*describe design ideas (either through drawing, models and/or verbally) or potential outcomes*".

In Athena, all students drew a rough sketch, close-up drawing, and perspective drawing to communicate their design idea. Students naturally referred to their drawing when

Figure 6.7
Rough sketch of Robob



describing their design as evident in their conversations with Jean. Some of the drawings are shown in Figure 6.7, Figure 6.8 and Figure 6.9 as evidence. The figures indicated that the students could communicate their design ideas through a rough 2D representation. At Athena, students made top view, side view, front view, and views of the joints in addition to the rough 2D sketches. At Minerva, students drew rough drawings for their two prototypes of water-filter.

Jean did not have dialogue about the accuracy of the 2D drawings on any parameter such as the scale of the drawing, accuracy, or labelling. Sarah-Jane, on the other hand, scrutinised the drawings as evident in the dialogue she held with the students in Lesson 2 and Lesson 4 (example of dialogue T2-Week 2-min 18:57-20:41 in page 143). However, Sarah-Jane did not comment on how students could use the 2D models more efficiently.

Figure 6.8

Multiple views of Robob

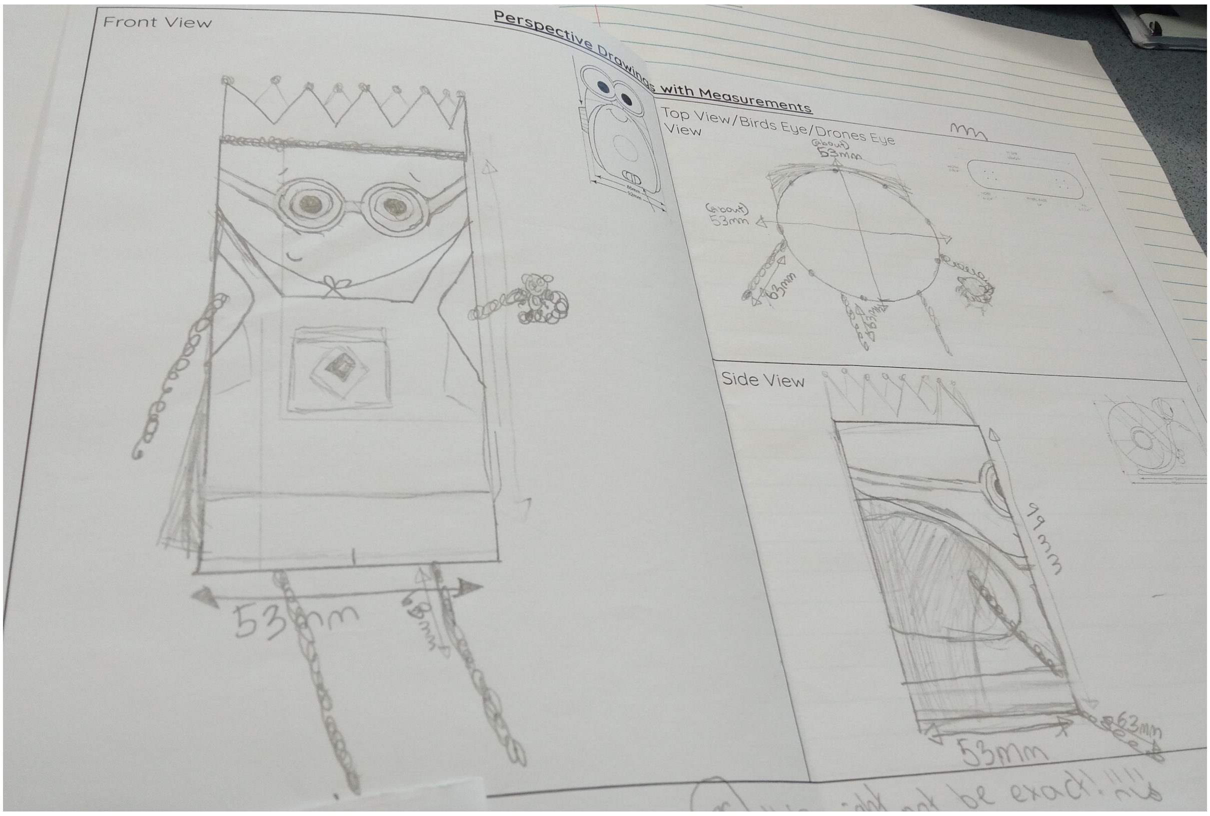


Figure 6.9

Exploded view of Robob

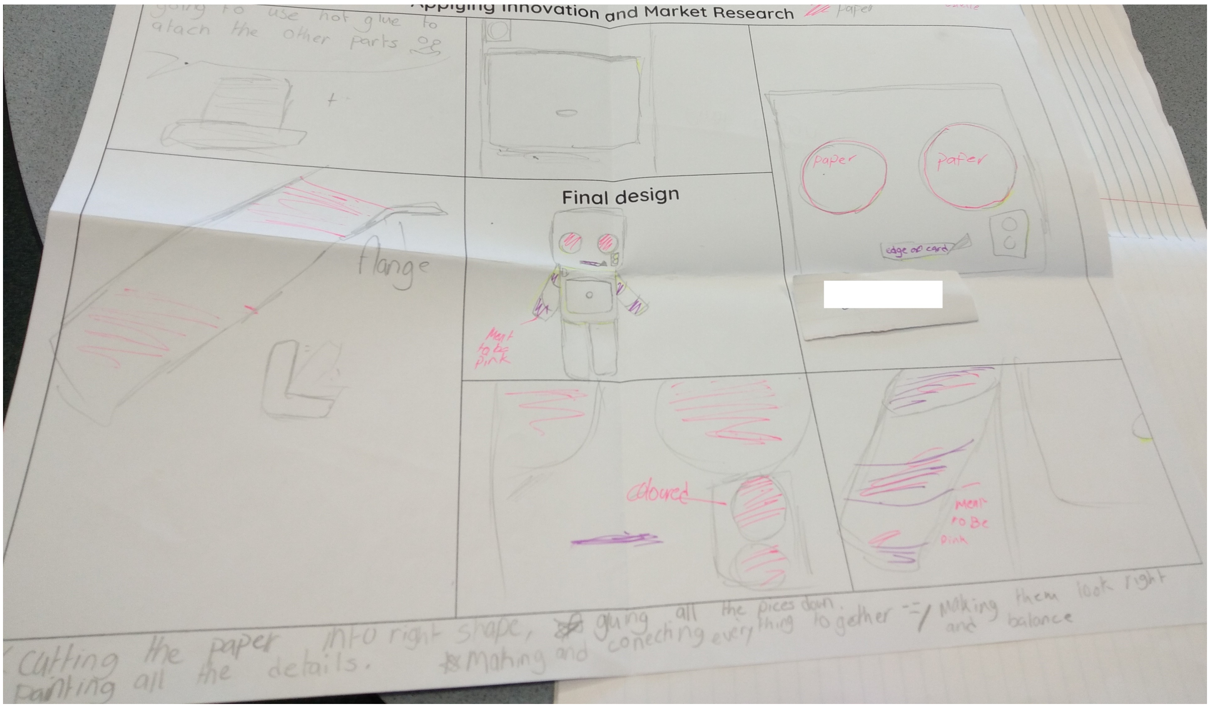
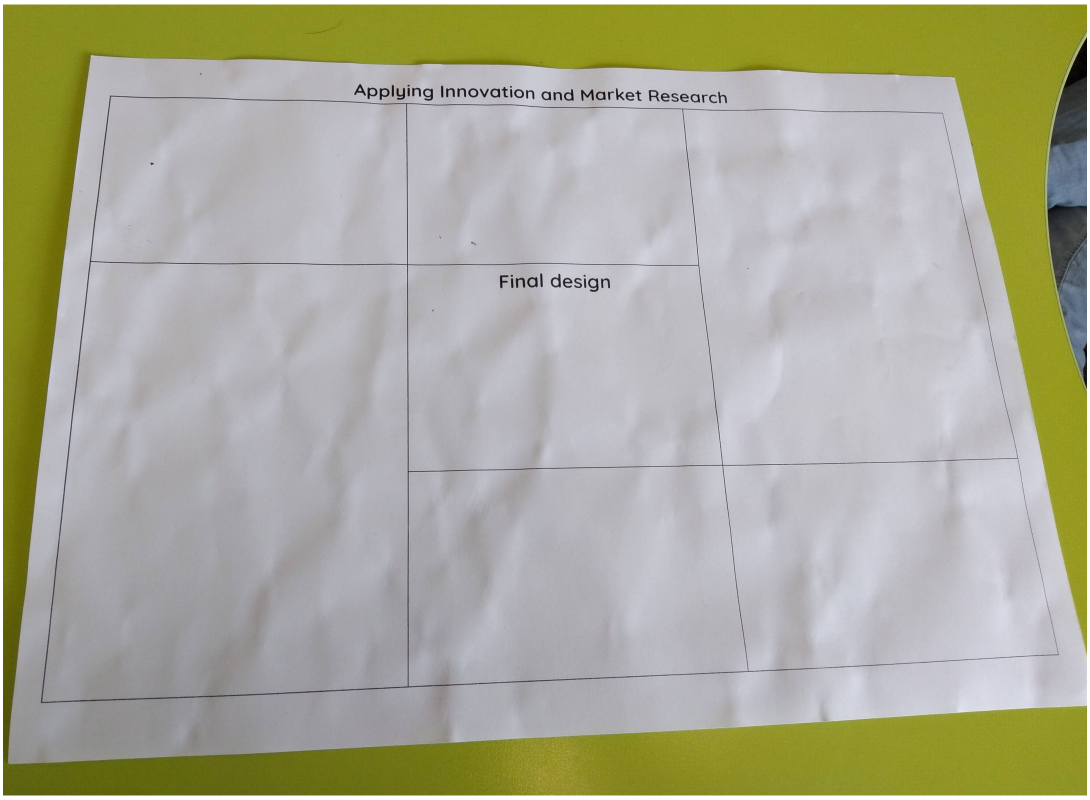


Figure 6.10
Exploded view template introduced by Jean



The lack of corrective feedback on the skill of 2D drawings was one of the limitations of Jean's and Sarah-Jane's technology unit.

Jean introduced a new type of 2D drawing - to draw close-up views of the joints in the cardboard unit - so that students could think in more detail about their final technological outcome. The introduction of new drawing (Figure 6.10) was in line with the teacher guidance notes for the Level 3 IoP "*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*" (Te Kete Ipurangi, n.d.-b). In the explanation of why the detailed drawing was needed and in a further group discussion on a question from the framework "How does drawing the plan help your group?", Jean was partially fulfilling the requirements of Level 3 AO "*Understand that different forms of functional modelling are used to inform decision making in the development of technological possibilities*" (Te Kete Ipurangi, n.d.-b) for the component TM and strand TK.

Jean explained to the whole class why the detailed drawing was needed and what was expected in the different boxes. Jean asked everyone to focus on the joints and think of attachments at the joints. Students demonstrated learning about this AO through their replies in the group discussion and by drawing different views of their technological outcome. Some of the replies by students during the group discussion were "*When we are building (the technological outcome), we looked at our plan and thought what is missing*", "*If you did not draw the plan, you would not be able to make it*", "*My plan helped me with the measurements*" (T1-Week4Day2-A1 min 15:57). Once the initial design phase was undertaken, teachers needed to consider how they facilitate students with making and evaluating prototypes.

6.1.5 Student learning about how to make and evaluate their technological outcome

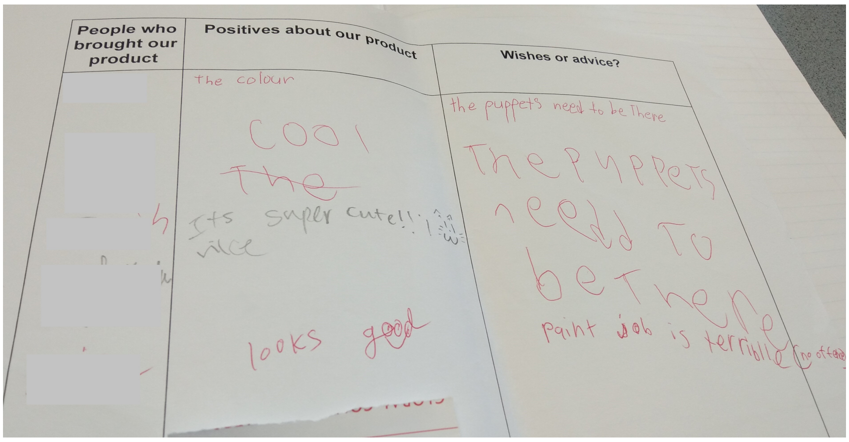
In the NZC, the making of a technological outcome is part of the strand TP and component ODE. The relevant student indicators for Level 3 for are "*produce and trial a prototype of the outcome*" and "*evaluate this outcome against the key attributes and how it addresses the need or opportunity*". (Te Kete Ipurangi, n.d.-b). Students made the final technological outcome at both schools.

There was little dialogue between Jean and the students during the making process. On the last day set aside for making, Jean asked students working on their cardboard outcomes, to set a goal for that day and walked around to ensure every student finished their outcome that day. In her walking around, she spotted four groups that she judged did not have creative designs. To these students she asked them to think if they could do something more to improve their design. Jean told one group that they had not followed her earlier suggestion of making their toy car mobile. She praised two groups for well completed technological outcomes and she helped two other groups with some of the design issues they were having. It was in dialogue with the students that Jean was able to take stock of everyone's designs and push for completion. All students produced a prototype of the outcome – however, the outcomes at Athena were not evaluated against key attributes although they met the design brief.

At Athena, for the students, it seemed important to make sure their technological outcome was "sold" in the market. There were 13 technological outcomes "for sale". Only five customer feedback sheets were available for analysis. However, other students mentioned in the reflection that their technological outcomes sold except for Dev, Vijay, and Noah whose 3-in-1 technological outcome was priced at NZD 13 and was judged as too expensive to buy. When asked about what their customers thought about their technological outcome, only one boy read out from the customer feedback. Two students (one male, one female) said that five customers bought their technological outcome on the market day. One other student acknowledged that they got a negative feedback

Figure 6.11

Customers who bought and gave feedback for Leo's product



about their gluing of the technological outcome. The rest of the students felt that their customers liked their designs especially if the technological outcome had been bought on the market day. If the technological outcome was not bought, the student likely replied that the customer liked the technological outcome, but it was too expensive. In case of Leo who said that his technological outcome fell apart during the market, he still found buyers for the technological outcome as recorded in the customer feedback sheet (see Figure 6.11). The replies implied that the students preferred to listen to only positive comments. Students choosing to listen to only positive comments seems natural and hence, a further dialogue could have helped students reflect on evaluation of their outcome.

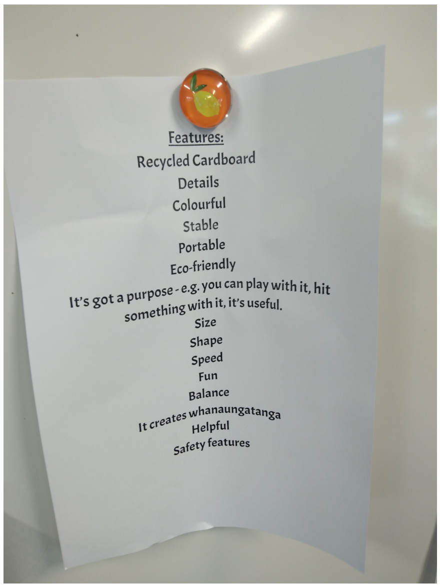
At Minerva, Sarah-Jane monitored the process of making but did not comment too much on the making process unless students ran into some trouble such as cutting the bottles. The making process was relatively simple at Minerva as typified by a student commenting "*Spent three hours on the plan and five minutes to make it*" (Researcher notes dated 30 August 2019). At Minerva, the students evaluated their technological outcomes by passing dirty water through their water-filter. Thus, the students made and evaluated the technological outcome.

6.1.6 Student learning in design and visual communication

Design and visual communication was a technology learning area only at Athena. Jean had students make a logo and advertising poster for the final market day. The process of making posters is part of the technological area Design and Visual Communication (DVC). Making the poster started the chain of design process once again as the poster is a separate technological outcome. The making of posters follows the same three strands – TP, TK and NT. By making an advertising poster, the AOs that were met are explained

(a) *Advertisement in a cereal box given as example*

(b) *List of features students could use in the advertisement*



below (Te Kete Ipurangi, n.d.-b):

- Level 2, BD: Explain the outcome they are developing and describe the attributes it should have, taking account of the need or opportunity and the resources available.
- Level 2, ODE: 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.

After making some logo options and choosing a final logo, the students got peer feedback and then teacher's feedback. For the poster, all students started off with a plan. Jean asked students to write down three features as the three main ideas that they would use on the posters. She helped students collate a list of features and gave examples of advertisement that used exaggerated language (Figure 6.12a). After the plan was made and Jean checked everyone's plan, she asked the students to make a mock-up which was also checked. Finally, the students could copy their final advertisement into an A3 sheet of paper and make it attractive. The final posters were then ready for display along with the technological outcome.

By talking the students through their draft, Jean ensured that every student had a poster. Some of the posters from the classroom are shown in Figure 6.6 as evidence that students demonstrated learning at Level 2 AO in BD and ODE in design and visual communication.

6.1.7 Summary

In this section, the evidence for student learning against the technology curriculum objectives in the NZC was discussed. To summarise the evidence, the students at Athena and Minerva refer to Table 6.1.

Table 6.1: Student learning against technology curriculum

Strands	Components	Athena	Minerva
Technological Practice (TP)	Brief Development (BD)	Level 3: Describe the key attributes that enable development and evaluation of an outcome Level 4: Justify the nature of an intended outcome in relation to the need or opportunity Level 4: Describe the key attributes identified in stakeholder feedback, which will inform the development of an outcome and its evaluation.	Level 3: Describe the nature of an intended outcome, explaining how it addresses the need or opportunity
Technological Practice (TP)	Planning for Practice (PP)	-	-
Technological Practice (TP)	Outcome Development and Evaluation (ODE)	Level 3: Describe design ideas (either through drawing, models and/or verbally) for potential outcomes Level 3: ...develop an outcome to address the need or opportunity. Evaluate this outcome against the key attributes and how it addresses the need or opportunity	Level 3: Describe design ideas (either through drawing, models and/or verbally) for potential outcomes Level 3: ...develop an outcome to address the need or opportunity. Evaluate this outcome against the key attributes and how it addresses the need or opportunity

Continued on next page

Table 6.1: Student learning against technology curriculum (Continued)

Strands	Components	Athena	Minerva
Nature of Technology (NT)	Characteristics of Technology (CT)	Level 3: Understand how society and environments impact on and are influenced by technology	-
Nature of Technology (NT)	Characteristics of Technological Outcome (CTO)	Level 3: Describe possible users and functions of a technological outcome based on clues provided by its physical attributes Level 4: Understand that technological outcomes can be interpreted in terms of how they might be used and by whom and that each has a proper function as well as possible alternative functions	-
Technological knowledge (TK)	Technological Modelling (TM)	Level 3: Understand that different forms of functional modelling are used to inform decision making in the development of technological possibilities	-
Technological knowledge (TK)	Technological products (Tp)	Level 2: Understand that there is a relationship between a material used and its performance properties in a technological product.	Level 2: Understand that there is a relationship between a material used and its performance properties in a technological product.

As discussed in detail in this section, there is evidence that students learned to analyse the brief and explain what they were making but limited evidence that they could explain why. There is no evidence that students can write a list of attributes for developing their outcome and limited evidence that they can evaluate their outcomes against the list of attributes. There is evidence that students understood the importance of consumers in the design process and designing a technological outcome for the consumer and not to personal taste. Students at Athena got experience working with different materials and there is evidence that they can explain how the properties of the materials contributes to the functional properties of the technological outcome. Students had wider variety of experience with varied 2D representations. All students could develop an outcome that met the brief with limited ability to evaluate the outcome. Students, in addition, demonstrated knowledge about design and visual communication and could develop an advertising poster targeting a specific consumer.

Students at Minerva showed evidence that they could analyse the brief and knew the importance of water -filter. They showed evidence that they knew the properties of the components of the water-filter and how they impacted the working of the water-filter. Students knew to sketch out their ideas in 2D drawing to explain their technological outcome. Students could develop their technological outcome and evaluate the outcome. Developing a list of attributes was taught by both the teachers in a limited way.

There is evidence that dialogue between the teacher and the student(s) played a key role in demonstrating student learning as well as for focusing the students' attention on the specific objective. Besides the technological objectives from the curriculum, evidence from this study showed that teachers had their own priority objectives while teaching the unit that went beyond the technology curriculum objectives. The data related to those objectives are explained in the next section and student learning evidence is provided for each objective.

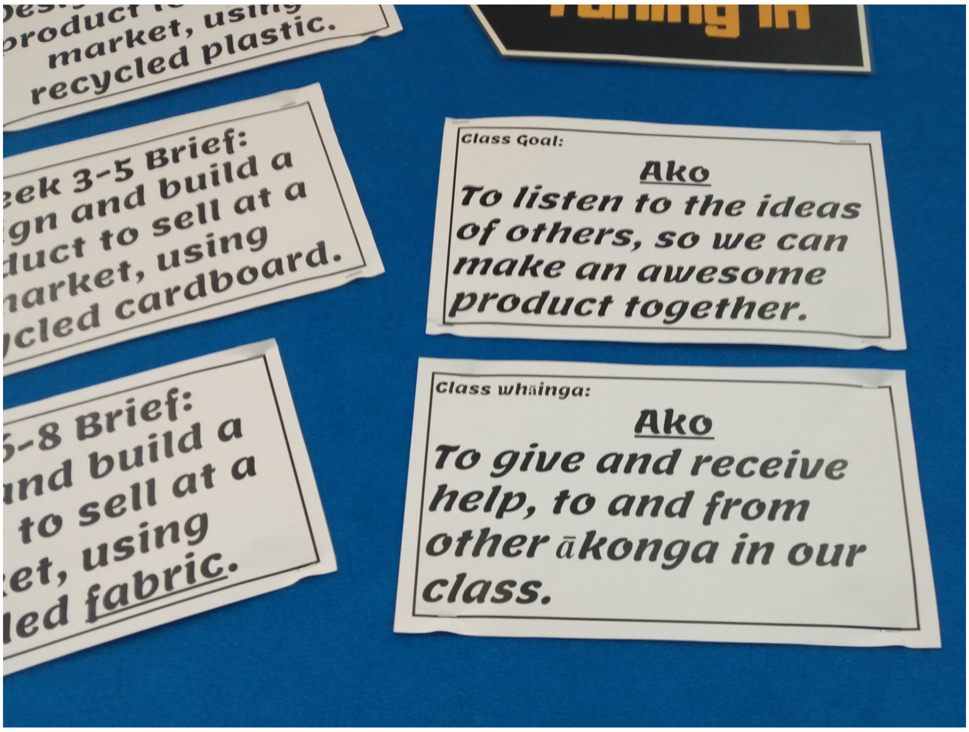
6.2 Dialogue and teacher's priority objectives

In addition to the technology objectives, Jean had other priority objectives for the unit which were displayed on the soft board (Figure 6.13) for students or stated to me in the interviews. These objectives were to develop students' collaboration, creativity, and problem solving. Sarah-Jane shared the priority objectives of developing students' collaboration and problem solving. In addition, she wanted students to learn to reflect. The student learning for teacher's priority objectives are discussed in detail in this section.

6.2.1 Students learning to collaboratively

Both teachers aimed for students to work collaboratively in the technology unit including learning to work with others and valuing others' inputs. Working collaboratively fulfils the key competency "Relating to others" (Ministry of Education, 2018a) in the NZC. At Athena, the classroom goals for the semester were "*To listen to the ideas of others, so we can make an awesome technological outcome together*" and "*To give and receive help, to and from other ākonga (students) in our class*". Jean felt working collaboratively in groups would help students to listen and to give and receive help.

Figure 6.13
Teacher objectives at Athena



She started the unit with showing a video about group work and spoke about why working in groups is important. She asked students to form groups where each group could have two or three members. She suggested that students choose someone they had not worked with before. Additionally, Jean asked the questions "*Who have you helped this week?*" and "*Who helped you this week?*" as part of the reflection questions for the first two weeks of the cardboard cycle which were not from QFT-P and the question "*How does working in a group help with your design?*" which were from QFT-P.

At Athena, in response to the reflection question about who helped them and who they helped, most students mentioned their group mates. Harper and Ria demonstrated the learning from the class goal by saying in their reflection "*Harper would have ideas and you wouldn't have your partner's ideas if you were not in a group*" (Studentreflection-Week4-Ria-Ruby) in response to the QFT-P question. Ria mentioned that Harper helped her and that they "*would not be where they are without Harper*" (Studentreflection-Week4-Ria-Ruby). In response, to the QFT-P question "*How does working in a group help your design?*", most students replied that having extra hands made them finish the technological outcome faster. For example, Ria and Emily alluded to having others' ideas and feedback. From the reflection videos, the student learning in relation to the class goal is evident. Jean's goal of wanting students to work collaboratively also seemed to be successfully demonstrated by all but three students.

Students were able to see the positive side of working together that they expressed through their replies to the reflection question.

At Minerva, Sarah-Jane wanted the students to work in groups so that they could learn to work collaboratively. Although Sarah-Jane did not express it in any of the interviews to me that working collaboratively was key goal for her, she mentioned to the students that they needed to reflect on how they collaborated with each other. At Minerva, students demonstrated working together by making both prototypes in a group and in the reflection dialogue and videos. During the reflection, in dialogue with Sarah-Jane, students mentioned their struggles and successes with group work. For example, Aisha's dialogue with Sarah-Jane presented below explains that Aisha and her group struggled with working together in the beginning, but they felt the benefits of working together (T2-Week 4-min 22:45).

> Sarah-Jane: What did you struggle with?
> Aisha: We struggled with collaboration at the start. Nobody was listening to other people's ideas.
> Sarah-Jane: At the start? So, you got better?
> Aisha: Yes, we started listening to each other's ideas.
> Sarah-Jane: What was the payback for that? What was the benefit of you listening?
> Aisha: We understood more and got through faster. Everyone understood it.

Through the unit, Sarah-Jane spoke to some groups about not being able to work together. She would have dialogue in those groups and ask them what they could do better. One such group was Blake, Amir, Sarah, and one other student. Sarah-Jane told them to sit together and talk to each other. However, Amir specifically struggled with working in the group. During their reflection dialogue, Sarah-Jane and the group had the dialogue given below where the group explained their struggles working together. The group recognised what they did and how they might do better which demonstrates their learning about group work (T2-Week 4-min 34:20).

> Sarah-Jane: What were your challenges? One was collaborating.
> Sarah: One of the challenges was working together and sharing ideas.
> Sarah-Jane: So why was it so hard?
> Sarah: Because two of us wanted to go our own path and the other two wanted to do something else.
> Blake: We all had a different idea of it. And we were not really with each other, and they did not have the chance to say their ideas.
> Sarah-Jane: So, the actual sharing? Did you have a talk with each other?
> Group: Yes.
> Sarah-Jane: What will you do about that next time?

> Blake: Try to work together more.
> Sarah-Jane: Yes, but what would that look like?
> Student: Before we start, we will share ideas and we can agree on things and disagree on things.
> Sarah-Jane: Nice
> Student: We would have an idea of what others are thinking
> Sarah-Jane: So next time, everyone gets to share. This is why collaboration is so good. I listen to one person's idea, and it sparked another idea. Before you even start, you grade the expectations of the group. You have a treaty among the group. What do you think about that? So, you all agree on a treaty on how the group has to be run? It doesn't have to take more than 5 minutes, right?
> Amir: It will take two minutes.
> Sarah-Jane: Yes. Good. For instance, like you said, everyone gets to share their ideas first and then you talk about it. Nice thinking. The challenge was also staying on task. So What are you going to do about that next time, Blake?
> Blake: Just get in and do it.
> Sarah: I think if we get to share all the ideas first because we were off task because we did not know what each other's ideas were, and we did not know what to do.
> Sarah-Jane: Who wanted to be the boss? Was that an issue?
> Amir: (Inaudible)
> Sarah-Jane: Thank you for your honesty. So now you know what to do next time. If you think about it, from the beginning of the last year to now, you have made huge changes. You can be proud. You are still going to have some not so good days. But you have come a long way.

In the excerpt above, the students demonstrated that they knew they had difficulties in working together and with help from Sarah-Jane, talked about how they could improve the next time. They brainstormed ideas on what they could do better the next time. Thus, students at both schools demonstrated that they found advantages to working together and had some success in doing so and were at least aware of their struggles.

6.2.2 Students learning about problem solving

Both teachers in this study wanted students to develop their skills with problem-solving during the technology unit. Problem-solving is present in the NZC through the "thinking" key competency. Jean and Sarah-Jane mentioned repeatedly that their primary aim was to ensure that students developed problem solving skills. Jean mentioned in an interview that the making of technological outcomes was "*are really good little safe problems for them to come across*" (Last interview with Jean, lines 279-280). Jean did not have dialogue with the students about problem-solving experiences of the students while Sarah-Jane spoke about what challenges the students faced in the final two lessons.

Jean felt that students faced many such problems throughout, for example, she mentioned that one group struggled with painting over sticky tape. There is also evidence in the students' reflection, that they faced some problems that they succeeded in solving. For example, Andy faced problems in attaching the head of his robot to the body as the head was too heavy; Dev found it difficult to glue and attach the skewers; Harper and Ria struggled to incorporate a sharpener and a compartment where the pencil shavings would go; Olivia found the ears of the candy holder difficult; Leo broke part of his design which Jean helped him fix.

Some students mentioned they faced challenges, but they did not solve it. Harper and Ria did not add legs to the minion design; Noah went from making a complex safe to a cardboard box; Leo and Bao changed their complete design when they did not want to make the vending machine as it would take too long, and it would be too hard. Most students mentioned in the reflection that painting and gluing difficult in response to the question "*What was hard about making this product?*" but with no details on what was difficult about the painting and gluing because there were no follow-up questions included. A dialogue with the teacher in such cases would have been beneficial – for demonstration of knowledge as well as for student to reflect deeply on the problems they faced. Hence, at Athena, from the reflection questions and the dialogue in the classroom, evidence exists that students faced problems that they either solved successfully or they avoided the problem by changing the plan.

At Minerva, Sarah-Jane asked the students "*What did you struggle with*?" or "*What were your challenges*?" during the reflection dialogue in Lesson 4. Four groups out of seven, answered this question either in dialogue with the teacher or in the reflection videos. Two groups mentioned the challenges they faced in collaboration. One group succeeded in working better with each other and the other group had discussion about what they could do better next time. Ana and her team felt that their challenges were in researching the different components and learning more about the efficiency of each material. Jay and his team felt that they faced the challenge of not knowing the order to put the materials but they overcame it by taking a risk. Students also showed that they solved problems in making the prototypes. While building the first prototype, only one group got visually clear water. However, while building the second prototype, only one group did not get visually clear water. Students evidently solved how to make their filter more efficient through research on the components.

There is evidence that students at both schools faced challenges and some students, some of the time faced the challenges and problem-solved while some of the time, they ignored the problem by working around it to develop their technological outcome. All the evidence presented here about problem-solving came from the student responses to the questions from QFT-P.

6.2.3 Students demonstrating and improving creativity

Jean wanted students to be more creative in their cardboard technology unit. Creativity is present in the NZC through the "thinking" key competency. At Athena, in the earlier plastic unit, Jean felt that the students were not creative enough in their design and had chosen to be quite "safe" with what they did. Consequently, she wanted the students to take more risks in the cardboard unit. She had a talk with the students about being too safe with the design – she asked them to consider being more creative. On day 1 and day 2, most of her dialogue with the students were about being more creative with the design. At Athena, it was noted that Jean asked seven groups out of the 12 to make their design more creative. By creativity, Jean meant inclusion of a moving part which she explained in a whole class discussion and in individual dialogue. Table 6.2 shows the students' initial plan and the changes after Jean asked them to make the design more creative. Of the seven, three groups did not make any changes. Four groups were not asked to make any change as Jean felt that their designs were creative enough.

While Harper and Ria incorporated Jean's suggestion, Emily and Brooke were given a direct instruction by Jean to make their car move but Emily and Brooke made a stationary car. Isla and Nicole were told to make their design creative but no direct suggestion of what exactly to do and Isla and Nicole did not change their design. On the other hand, when Ava, Mila and Ruby were told to think about a creative design, and they changed their idea from a basketball field to a doll house. While Jean did not suggest anything about their designs in the first week to Willow and Leo and Bao, in the second week, she suggested to these students later to make some changes which the students did not incorporate. Although some of the designs started with creative ideas and Jean focussed on asking for other designs to be creative, the evidence shows that the teacher's feeback is not always incorporated.

While creativity was not a target at Minerva and there was no dialogue about creativity, the students at Minerva exhibited creativity in one instance during the evaluation of the second prototype. After all the students tested their filters, some of the groups decided to combine their filters to see if the water was cleaner than the individual filter (Figure 6.14). This act of creativity was spontaneous in the classroom and was initiated by the students.

Table 6.2
Changes in design based on Jean's instruction to be creative

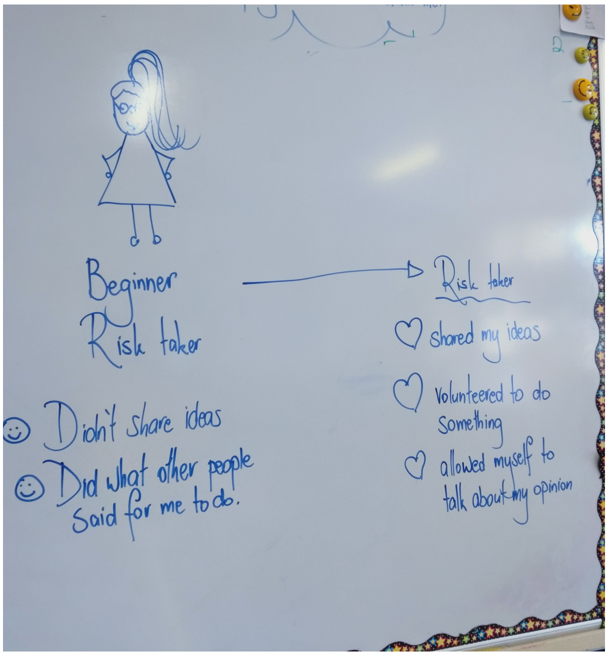
Group	Initial design	Change of design
Harper and Ria	Minion pencil holder with rubber holder	Minion pencil holder with inbuilt sharpener and rubber holder
Olivia	Pig shaped candy holder	Idea suggested by Jean to pair up with George and combine the designs but not taken by Olivia or George
George	Action figures, toy	Idea suggested by Jean to pair up with Olivia and combine the designs but not taken by Olivia or George
William	A game	Idea for the game suggested by Jean
Ava, Mila, and Ruby	Basketball court (toy)	A dollhouse (toy)
Emily and Brooke	Minion (toy)	Car (movable) for minion (toy)
Noah, Vijay and Dev	A foosball table, a safe and a Beyblade stadium (3-in-1)	No suggestion given by Jean
Andy + 2	A robot (toy)	No suggestion given by Jean
Leo and Bao	A coin operated vending machine	No suggestion given by Jean
Willow and Amelia	A basketball court with a catapult launcher and jewellery box	No suggestion given by Jean
Lucas and Sophie	A robot with storage drawer	No suggestion given by Jean
Isla and Nicole	A fox shaped pencil holder	No change made by student despite Jean asking them to be more creative

Figure 6.14

Combining multiple filters by students of Minerva

Figure 6.15

How to reflect? Whole class discussion by Sarah-Jane



6.2.4 Students learning about reflection

At Minerva, Sarah-Jane wanted students to develop reflection skills about their learning. Reflection is part of the "Thinking" key competency in the NZC (Ministry of Education, 2018a). Sarah-Jane wanted the students to reflect on their learning from the unit. She asked the students to work on specific questions in their reflection videos. The questions for the reflection videos were – *How did you collaborate as a group, what skills have you used, what new learning have you experienced, what challenges did you face and how did you overcome them, what wonderings do you have now, how will you use your new learning in the future.* Of the six questions, four questions are from the QFT-P. Sarah-Jane had a whole class discussion on how to reflect and how the students could gauge their growth as she explained on the whiteboard (see Figure 6.15). As students made the reflection videos, she reviewed and commented on the videos. Some of the critical questions/comments were "*Where is the evidence for the skills you learned?*", "*You have not talked about what you really learnt. What did you learn from the design? Why did you change the prototype 2?*", "*Go back to the modelling book and make a plan for your reflection video.*", "*You have only one aspect of your learning, collaboration.*" (Researcher notes of 6 Sep 2019).

Students demonstrated their ability to reflect in their the reflection videos. Reflection videos for three from the seven groups were available. All groups answered questions relating to challenges they faced, what they would do for the third prototype, and the new learning they experienced.

6.2.5 Summary

In this section on learning based on teacher's priority objectives, evidence that originated from the questions in the QFT-P, suggests that students at both schools learnt to work with each other more productively. For Athena, most students tried working in groups and gave positive comments on their experience working in groups and at Minerva, students reflected deeply on the challenges of working in groups. In one case, in dialogue with Sarah-Jane, the group planned for working better next time. Students at both schools recognised that they faced problems during the unit. At Minerva, due to specific dialogue with the teacher, students explained in a structured way what challenges they faced and how they overcame these challenges. While at Athena, students mentioned the challenges in reflection videos, but they did not explain or reflect deeply on the challenges. Students at Athena focused on creativity due to their dialogue with Jean. However, despite Jean's heavy focus on creativity, all students did not uptake the teacher's feedback on creativity. Sarah-Jane wanted the students to reflect in a structured fashion about their learning for the unit and she spent two lessons working on the reflection videos and the evidence shows that students were beginning to do that. Thus, student learning at both the schools was not only in TE curriculum objectives but also objectives that derived from key competencies in the NZC that the teachers prioritised in the classroom. This learning was demonstrated and strengthened through dialogue in IFA.

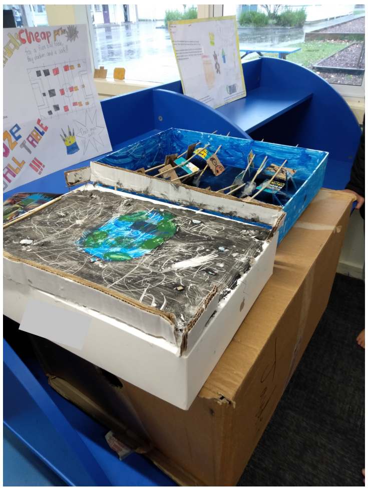
The next section is not directly related to the technology curriculum or teacher's priority objectives but on the findings about students' actions on teacher's feedback. Teacher feedback is an important response to noticing or eliciting learning from students. This next section focuses on students' uptake of teacher feedback.

6.3 Dialogue and students' uptake of feedback

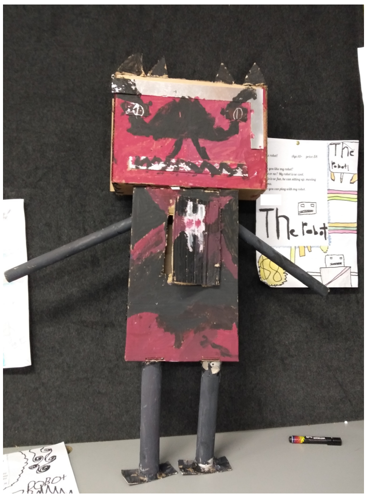
All students in both the classrooms developed a technological outcome and had feedback from the teacher through the whole of the unit. However, this section will focus on data from Athena as the student uptake of feedback is best exemplified from Athena's data. Section 6.2.3 described how Jean interacted with each group and what the students decided to do after the dialogue with Jean. This section is divided into four sections based on student responses in section 6.2.3: as students who were not asked to change their design, students who were given the feedback to change their design but did not change, students who received the feedback to change their design and changed, and students

Figure 6.16

Technological outcome by students not asked to change their design



(a) *Noah and group - 3-in-1 foosball, beyblade stadium, and safe*



(b) *Andy and group - Robot*

(c) *Lucas and Sophie - Robot with storage drawer*

who changed their technological outcome without having a dialogue with Jean.

6.3.1 Students who were not asked to change their design

Jean did not ask four student groups to change their design for the technological outcome considering their designs to be “creative” enough. As mentioned earlier, by creative Jean meant that a moving part was included in the technological outcome. Of the four groups, Noah and his team, Andy and his team, and Lucas and Sophie were the students who did not receive any suggestions to change their design and stuck to their original plan. Figure 6.16 shows the photograph of the final technological outcome by all three groups.

The example of Noah and his team is explained in detail to illustrate this finding. Noah, Dev, and Vijay attempted to make a 3-in-1 technological outcome of foosball table, *Beyblade* stadium, and a safe. Each one was to take responsibility to make one of the technological outcomes. However, they later said in the reflection video that they had no time to make three things. Each one individually struggled with their component as well. Dev struggled to get the skewers glued together for the foosball table; Noah was confused how to proceed with the safe and finally, just used a cardboard box as is; Vijay struggled with the painting of the *Beyblade* stadium. In the reflection videos, they mentioned how they helped each other to make their components. Jean had multiple conversations with them over the unit on their design. An example of the conversation is given below (T1-Week3Day1-A1-min 36:11)

Jean: What is the most important feature of your design?
The group debate which is the most important part of the design (mistaking feature for important part).
Group: The safe
Jean: How will you make sure that the feature stays on your product?
Vijay: We will take our time and not rush.
Jean: Make sure that the safe stays in the design.

As can be seen from the conversation, Jean did not seem to pay attention to what the students were answering in response to the question about important features. The students replied with a part of the design – the safe. Jean told them to keep that feature in the final outcome. The next conversation with the group was later in the week (T1-Week3Day5-M1-2-min 1:50). While reading the conversation, Jean's responses are to be noted especially the responses in red and blue.

Jean: What have you learnt from your market research?
Vijay: We need support if we are going to make it. Like the support beams and all that so that it doesn't fall apart.
Jean: Is that what you learnt from the market research?
Vijay: Because our last design, it kept falling apart at the arms. And it was only NZD 5. I don't think this can be NZD 5 worth because (cross-talk among the team mates)
Jean: You are telling me that you need more supports. That learning has not come from market research. That learning has come from the last product because you think you need more – It wasn't strong enough? (Group says yes) Is that what your market told you when they were buying it, your consumers told you?
Vijay: Yes. Some of them.
Jean: Oh, ok. That is kind of like market research then. (Interruption from another student lasting few seconds)
Jean: What did you learn from interviewing your customers?
(Interruption from another student lasting few seconds)
Dev: Lot of customers want blue as the colour of the soccer table. Why blue? Why not green?
Jean: Did you ask them that?
Dev: Yes. They said that they liked that colour. They want something different.
Jean: So, you are looking at the research. That is a good idea.
Dev: People like to play with Beyblade and also keeping their stuff safe. (*inaudible*)
(Interruption from another student)
Jean: What is it that you have changed after your market research?
Vijay: I changed the design and also these parts. These are supposed to be yellow lines and I have turned them into beams thinking that it would easily break.
Jean: What did the customers say they wanted in their product?

Vijay: Wanted to have some more colour. Painting the edges.

Jean: So you changed your design after the market research yesterday?

Group: Yes.

Dev: (*inaudible – alluded to changing the corner kicks*)

Jean: What is your plan to make the product? What are the key steps?

Dev: I think the main part is paint because there is a lot to paint.

Noah: Not the inside of the safe.

Dev: Yes but Vijay and I have to paint everything.

Jean: Do you think you will be painting at first?

Dev: I would like to do outlines of the face with pencil. Then I will start painting.

Vijay: I will use sticks to draw the lines and then paint inside the lines.

Noah: It will be easy for me, I only need to paint the outside.

Jean: Is the painting the first thing you are going to be doing?

Dev: No I think it will be the outlines for me.

Jean: What I would like you to do is to write at the bottom of this drawing, the key stages to make your design. 3-5 steps of making your design.

From the above dialogue, on multiple occasions Jean asked the students the same question (coloured in red) repeatedly in different forms until she got an answer. The next question she asked (coloured in blue) also had to be repeated twice and she did not get an answer besides painting. Through this dialogue, Jean was interrupted thrice by other students. In this dialogue, Jean listened carefully to the students and responded to their answers. However, due to difficulty in communication between her and the group, Jean spent 5-6 minutes on eliciting and affirming two aspects and possibly, found it difficult to ask more questions. For example, Jean did not challenge the students on how they would combine their technological outcome or any other detail about a combined technological outcome as theirs was a 3-in-1 product. Jean interacted most with this group by speaking to them on four occasions in the two weeks of the making. However, those conversations were about specific detail like painting or gluing the skewers together. The teachers' responsiveness during the dialogue with this group is discussed in detail in the next chapter.

There was no evidence that Jean challenged any aspect of the design with Lucas and Sophie. With Andy and his team, Jean had more hands-on approach in helping at every stage of the design. However, there is no evidence that she had any dialogue with Andy and his team except in the beginning to help Andy with brainstorm.

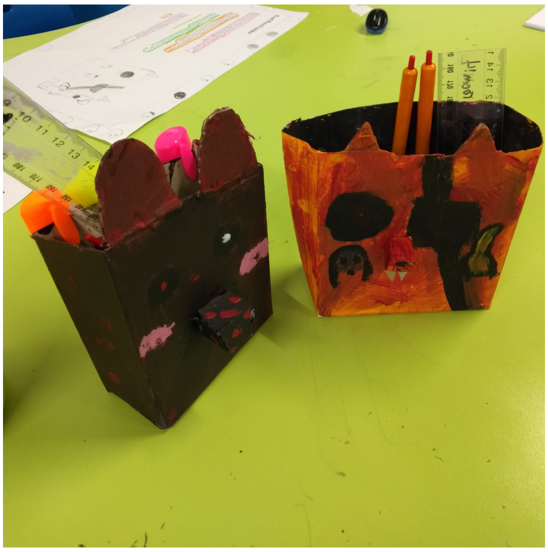
6.3.2 Students given feedback to change their design but did not make the changes

Two groups did not implement Jean's feedback to make their design more creative. Emily with Brooke and Isla with Nicole were two groups that were asked to make their

Figure 6.17

Technological outcome by students who were asked to change their design but did not

(a) *Emily and Brooke's car for a minion*



(b) *Isla and Nicole's fox shaped pencil holder*

designs more creative from the beginning. Their outcomes are shown in Figure 6.17 (except for Olivia's outcome). Brooke and Emily incorporated part of Jean's instruction. Isla and Nicole did not incorporate Jean's instruction.

Emily and Brooke suggested making a minion at first, but Jean told them to not be safe and come up with a creative design. The dialogue between Emily and Brooke and Jean is presented below (T1-Week3Day1-A1-min 10:34, and min 19:56) and was partly used in section 5.2.1.

> Jean: Does the product you designed have a purpose?
> Emily: It is a toy.
> Jean: It needs a purpose, and it is quite a safe design. Speak to Brooke.
> Emily: I also have this design for clothes rack for the minion.
> Jean: That is a bit more creative. Think more about the purpose. Decoration cannot be a purpose.
> *Brooke and Emily come back to Jean later.*
> Brooke: We want to make a car and make it move.
> Jean: How will it move?
> Brooke and Emily: We will put wheels and push it.
> Jean: Can you think of making it move without having to push it with your hand? Is there any other way to make the car move? (*No response*) How does a balloon move?
> *Inaudible reply*
> Jean: What about rubber-band? Have you seen a rubber-band powered car? So I

will put your name down. Part of the research you do is how do you move your car without having to push it.

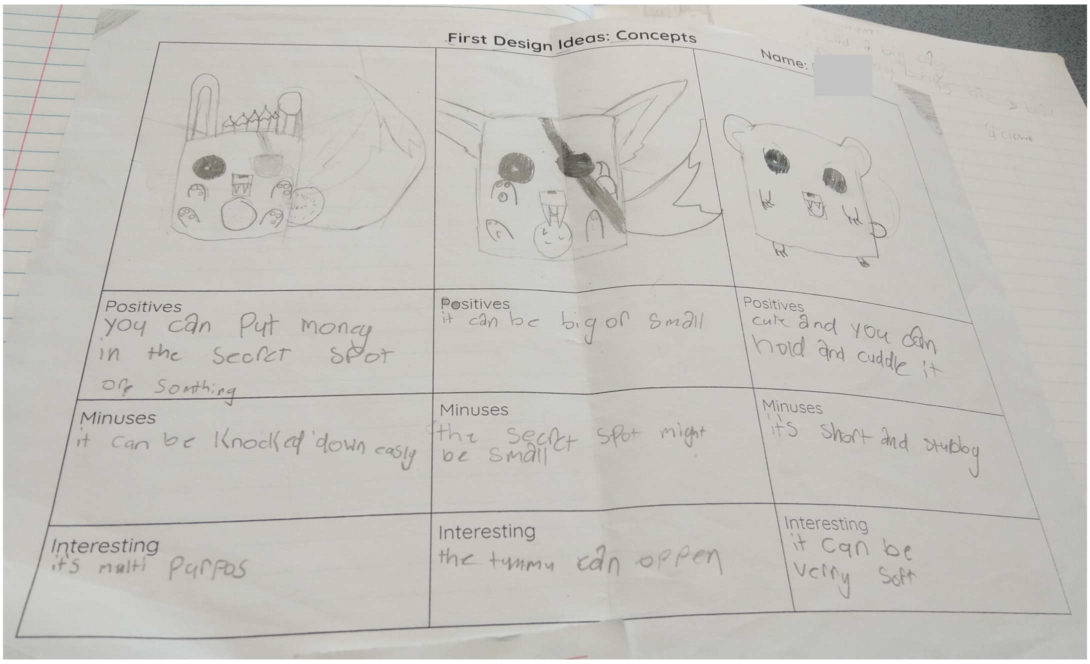
In the above dialogue, Jean challenged Emily and Brooke to be more creative. Brooke came back with the idea of making a moving car. Jean's responses show that she listened carefully and responded to the students' statement. She wanted the students to challenge themselves to move the car without having to push it. Although Brooke and Emily changed their early planned design of a minion toy to a car, they did not make the car movable. On one other occasion in the two weeks of making, Jean asked them about making their car move and asked them to use the laptops to search for more information, Brooke and Emily did not make the changes.

Isla and Nicole's initial dialogue with Jean was similar to the dialogue with Brooke and Emily. However, Brooke and Emily came back to Jean and proposed a new design, but Isla and Nicole did not come back to Jean. Jean had explained to them that they were being safe with the design. "*You have a container that looks like a fox. That is a bit safe*" (T1-Week3Day1-A1-min 22:50). The next day, Jean again asked Isla and Nicole what they had done to make their idea more creative. Nicole suggested that they could make the mouth open and close and could create a secret compartment. Jean felt that was more creative and asked them to think of two more ideas before making the PMI (Plus, Minus, Interesting chart) (T1-Week3Day2-M1-min 30:57-32:15). Figure 6.18 shows the PMI made by Isla and Nicole. In Nicole's PMI, she mentioned the secret compartment in 2/3 designs while Isla mentioned it in only one of the designs. The next time Jean noticed what the two of them made was on the second to last day of the making – towards the end of the second week of cardboard unit. On this day, Jean again asked Isla to incorporate the secret compartment. The next day Jean again asked both Isla and Nicole why their design was so simple, and she asked them to upgrade their design (T1-Week4Day4-A1-min 10:50, T1-Week4Day5-M2-min 00 and min 10:36). Considering that the final technological outcome did not have a secret compartment, it is evident that Isla and Nicole decided to stick to their initial idea and not incorporate Jean's feedback.

6.3.3 Students given feedback to change their design and changed their design

Two groups incorporated the feedback given by Jean to be more creative. Ava, Mila, and Ruby were the group that made a dollhouse. Ria and Harper made a stationary holder in shape of a minion. The outcomes of both these groups are shown in Figure 6.19. Both these groups were challenged by Jean to come up with creative ideas and both groups

Figure 6.18
PMI made by Nicole



followed the suggestion. The dialogue between Ria and Harper and Jean is as an example (T1-Week3Day5-M1-1):

> Jean: What is the purpose of your design?
> Harper/Ria: Holds pencils and pens. We can put a rubber in there (*pointing to design*) and pull out.
> Jean: Is there anything else that yours does?
> Harper/Ria: It is like a toy as well. You can take the teddy bear out of its arms.
> Jean: Girls, I wonder whether you can challenge yourself and put a drawer on your design as well as a little pull out for rubber. What if there is another compartment to put pencil sharpener or pencil shavings?
> Harper/Ria: At the back, we could have a drawer like at the bottom. (*Talking to themselves*) Pencil would get stuck halfway through because the drawer is around there.
> Jean: You could just put your pencil in there and sharpen it.
> Harper/ Ria: (*inaudible*)
> Jean: So, that might be it. Add the detail in to the technical drawing. Do you think your customers would like that? (*Harper/Ria nod*)..

In this dialogue, Jean gives clear direction to Harper and Ria on what they could add to their design to make it more creative. Harper and Ria work out the details in the dialogue with Jean and have a clear idea of what to do when they leave the dialogue. Similarly, in dialogue with Ava, Mila, and Ruby, the students suggest making a doll house and explain

Figure 6.19
Technological outcome of groups incorporating feedback

(a) *Doll house made by Ava and group*

(b) *Minion pencil holder made by Ria and Harper*

what they will do clearly. Before they leave a dialogue with Jean, they have a clear idea of a way forward.

6.3.4 Students who changed their outcome without consultation

Two groups changed their outcome during the making week and did not inform Jean about what they were doing. The students had done market research and sought stakeholder feedback on a different technological outcome. In changing the outcome without consultation with Jean, there was loss of opportunity to learn about the importance of customer feedback in the design process. Leo, Bao and Amelia did not make 2D drawings on their new technological outcome. The students also lost an opportunity to problem-solve.

Leo and Bao were to make a coin vending machine and they ended up making a puppet show stage. Amelia and Willow were to make a jewellery box topped by a basketball game with a catapult and they ended up making two separate outcomes – basketball court with no catapult and photo-frames. These outcomes are shown in Figure 6.20.

Figure 6.20

Technological outcome of student changing outcome without consultation

(a) *Puppet stage made by Leo and Bao*

(b) *Photo-frames made by Amelia*

(c) *Basketball game made by Willow*

Amelia and Willow and Leo and Bao had a dialogue with Jean in the beginning of first week where they told Jean what they were planning to make. Jean did not ask both the groups to change their designs. While Amelia had no further dialogue with Jean, Willow had one further dialogue with Jean. Jean had suggested her to make a net for her basketball court and research whether she had made a basketball or netball court (T1-Week4Day5-M1-min 26:00). However, Willow added a board behind the hoop for the net to make it a basketball court but did not make a net for the hoop. In the dialogue, Willow had indicated that she already knew the difference between basketball and netball court. So, it seemed like that was the only change Willow incorporated. Amelia made the photo-frames on the day before the market as she did not have an outcome by then. She was overheard saying that she was smart to have priced the photo-frames as NZD 1 and many students bought the photo-frame due to the low price. However, as can be seen from the photograph, the photo-frame is just a decorated piece of cardboard with nowhere to insert a picture.

Leo and Bao had three conversations with Jean over three weeks of the unit. Late in the second week, Leo told Jean that he changed his plan to make a puppet show as he did not have enough materials and could not make the vending machine but did not show a drawing to Jean. Jean assumed that they would have a full puppet show and she said they could sell the tickets to the show on market day (T1-Week4Day3-M3-min 15:00). Later, when I spoke to her about Leo's design, she said she had no idea when they changed their design which is not surprising since James had not informed her before changing the design and it was almost the end of the time set aside for making when he informed Jean. The next time Jean spoke to Leo was in the third week of the cardboard unit. Jean asked Leo and Bao to make some puppets to go along with their "stage" (T1-Week5Day1-M1-min 24:20). Two days later, she again asked Leo to make puppets when Leo was struggling to fix something that broke in his design. Jean helped Leo to fix the break. Leo and Bao did not add the puppets. During reflection, they both mentioned that they should have added some puppets. Leo mentioned that his technological outcome fell apart during market day.

6.3.5 Summary

To summarise, Jean had dialogue with only some of the groups and responded with constructive comments. With some groups, Jean did not have a dialogue – she did not actively listen and respond to the students' comments. In the next chapter, I will discuss the possible reasons for lack of dialogue. With students that Jean had a dialogue and gave feedback to change, if the change was discussed within the same dialogue or students discussed it proactively, then the students seemed to have followed through with the feedback. Students seemed to listen to feedback that had a solution and clear way-forward such as her dialogue with Harper and Ria. If Jean did not speak to the students and finalise an answer with them right away, students seemed to ignore her feedback. The implication of this finding will be discussed in the next chapter.

6.4 Chapter summary

This chapter started with findings on what students learnt against the TE curriculum, what students learnt in relation to the teacher's priority objectives and the uptake of teacher's feedback. As summarised at the end of each section, students demonstrated learning in some of the components of technology at least at Level 3 with brief development and outcome development and evaluation being the strongest of their learning. Both these components are in the strand Technological Practice. Students in both schools demonstrated learning at Level 2 in Technological products. Students were weak in developing a list of attributes and evaluating their outcome against the list of attributes.

On teacher's priority objectives, students demonstrated learning in working together and problem solving. Students at Athena were focused on creativity, although there was limited evidence that they learnt about creativity. Students at Minerva began to learn to reflect in a more structured fashion based on evidence from Sarah-Jane's whole class dialogue.

Dialogue between the teachers and the students provided the evidence for the students' learning and were the means for learning. Jean's dialogue about creativity allowed at least some of the students to make more creative designs and take risks with their outcome development. The dialogue also provided students space to learn about meeting the design brief, about materials, creativity and provided an impetus for students to finish their design. Through dialogue, student's learning was demonstrated in brief development, importance of consumer, outcome development, collaboration, and problem solving. Dialogue played an important role in most of the learning as they allowed the teachers to recognise student learning and extend the student learning further and additionally, served as a demonstration of student learning.

An additional finding that can be inferred from all the findings combined is that the teacher needs to ask questions or have conversations about every objective they want to achieve in the class after having taught the objective. The students' answers can serve as a demonstration of their learning and prompt students to think deeper about their learning. While section 5.2 of the findings on formative assessment suggested that reflection videos that students uploaded did not aid dialogue and could not be formative assessment, the analyses of the reflection videos in this chapter were the evidence for student learning. Hence, reflection videos can be included in the student portfolio of their work and thinking through the unit. Most of the reflection questions were from the QFT-P – thus, providing evidence that QFT-P can assist in the elicitation of student learning. Questions from the QFT-P proved to be good starting points to dialogue or for the reflection videos. Except for creativity, the teacher was able to ask questions from the QFT-P for all the other learning objectives.

The next chapter discusses the findings from the three findings chapters against existing literature to provide context and depth of understanding for formative assessment in TE. Findings will be discussed in response to the research questions.

Chapter 7

Discussion

> Every one has experienced how learning an appropriate name for what was dim and vague cleared up and crystallized the whole matter. Some meaning seems almost within reach, but is elusive; it refuses to condense into definite form; the attaching of a word somehow (just how, it is almost impossible to say) puts limits around the meaning, draws it out from the void, makes it stand out as an entity on its own account (Dewey, 2011, p. 174).

The three preceding findings chapters provided evidence from the data analysis of the study about the attributes of the QFT-P. In a design-based research, besides development of a concrete tool for solving an identified problem, theory construction forms a major part of the analysis (T. Anderson & Shattuck, 2012). The research questions to which this study aimed to respond were:

- What insights can be gained about Interactive Formative Assessment in Technology Education through analysis of teacher-student dialogue?
- How do teachers' beliefs and knowledge impact Interactive Formative Assessment in Technology Education?
- What influence does Interactive Formative Assessment have on student learning in Technology Education?

In this chapter, the responses to the research questions are discussed through three sections: Insights about IFA in TE, Teacher's practice and IFA, and student learning through IFA in TE.

7.1 Insights about Interactive Formative Assessment in Technology Education

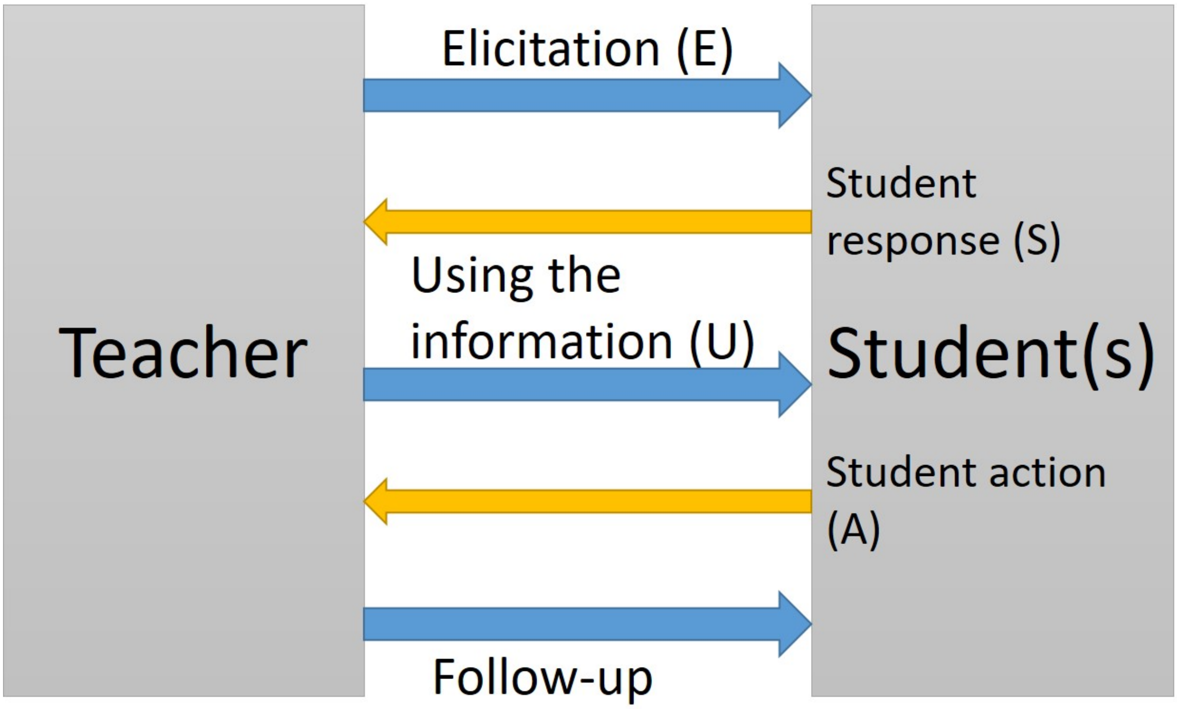
The purpose of analysing teacher-student dialogue in this study was to gain some insights into IFA as the existing literature is limited. TE educators have suggested that dialogue is critical to formative assessment in the TE classroom (Black, 2008; Cowie et al., 2013; Moreland et al., 2007) and one study confirmed this practice (Fahrman et al., 2020). Additional evidence for using dialogue in formative assessment exist in the field of science education studies (Correia & Harrison, 2020; Nieminen et al., 2021; Rached & Grangeat, 2021; Ruiz-Primo & Furtak, 2007; Sezen-Barrie & Kelly, 2017). The relevance of applying conclusions from science studies to this TE study seems valid due to the similar approaches in teaching science and technology in schools. Moreover, in NZ both science and technology have the same relative importance in the primary curriculum and are taught by the same teacher.

This section discusses the model of IFA in literature and the modifications proposed based on the data of this study. It is followed by a discussion of how teachers can make the follow-up process easier and finally with discussing why IFA is a complex process. This section aims to respond to the research question "*What insights can be gained about Interactive Formative Assessment in Technology Education through analysis of teacher-student dialogue?*".

7.1.1 Model of IFA in TE

Dialogue in IFA followed a specific pattern in this study. Teacher elicited information from the student(s) about their actions or their thinking and the student responded to the teacher. From this point, the teacher had multiple options for response and feedback. The teacher could ask students another deep probing question and have the students reply or ask them to do more research/ discuss among themselves or draw a plan in some detail. This exchange could go back-and-forth and usually ended with teacher and the student(s) discussing the next step. Based on pattern of interaction, a model of IFA in TE is explained in this section informed by the data from this study and building on the literature on existing models of IFA proposed by Ruiz-Primo and Furtak (2006, 2007) and B. Bell and Cowie (2001). Refer to Figure 2.1 and figure 2.2 in Section 2.1.5 of literature review chapter for the models of IFA in literature. The intention of my proposed model is to show the stages of IFA clearly and add to the existing knowledge about IFA. In bringing clarity to the stages of IFA, teachers can identify and classify their own practice against the model and have a mental check-list of complete or incomplete cycles. This awareness is important as some research has shown the benefits of complete cycle to the IFA practice (Nieminen et al., 2021; Rached & Grangeat, 2021; Ruiz-Primo & Furtak, 2006, 2007).

Figure 7.1
Extended IFA model with two added stages



Stages of Interactive Formative Assessment model

In the first stage, the teacher elicits information (E) from a student or group of students based either on noticing their learning or as part of routine follow-up in the classroom, while using the QFT-P. The student then responds (S) to the teacher eliciting information. At this point, the teacher could go back to the previous stage and elicit more information from the student and the student responds again. The dialogue could alternate between these two stages until the teacher then recognises the learning the student has been trying to explain. Once the teacher recognises the learning, the teacher uses (U) the information to guide the student learning to the next step in their learning through feedback. While the model so far follows the Ruiz-Primo and Furtak's proposed ESU cycle, two further stages are proposed based on the data from this study. The next stage is student acting (A) on the end point of the dialogue which could either be further research, discussion within their group, or working on the next step as decided in their dialogue with the teacher. After the student acts, the teacher follows-up (F) to ensure that the cycle is complete. Thus, the IFA model based on findings from this study in TE is Elicitation (E) – Student response (S) – Teacher using the information (U) – Student action (A) – Teacher follow-up (F), graphically represented in Figure 7.1

In many instances in the classrooms during this study, the teacher asked students to do a specific task at the end of the IFA dialogue such as thinking about some topic, or discuss with the group, or do a specific action to advance the technological outcome and understanding. Some students performed the task, and some did not. If the student did not perform the specific task, this would present another learning opportunity for the teacher to find out what the students were thinking and why they did not act. Otherwise there is a risk that the purpose of the IFA could be lost. Following up with students to ensure that students did the action was a major difference between Jean and Sarah-Jane's class. Sarah-Jane followed up with every group once she asked them to do more research or discuss with each other. Due to the way the study was conducted, it is not possible to state empirically whether the student outcomes were affected by the two extra stages proposed in this model - this is a limitation of this study.

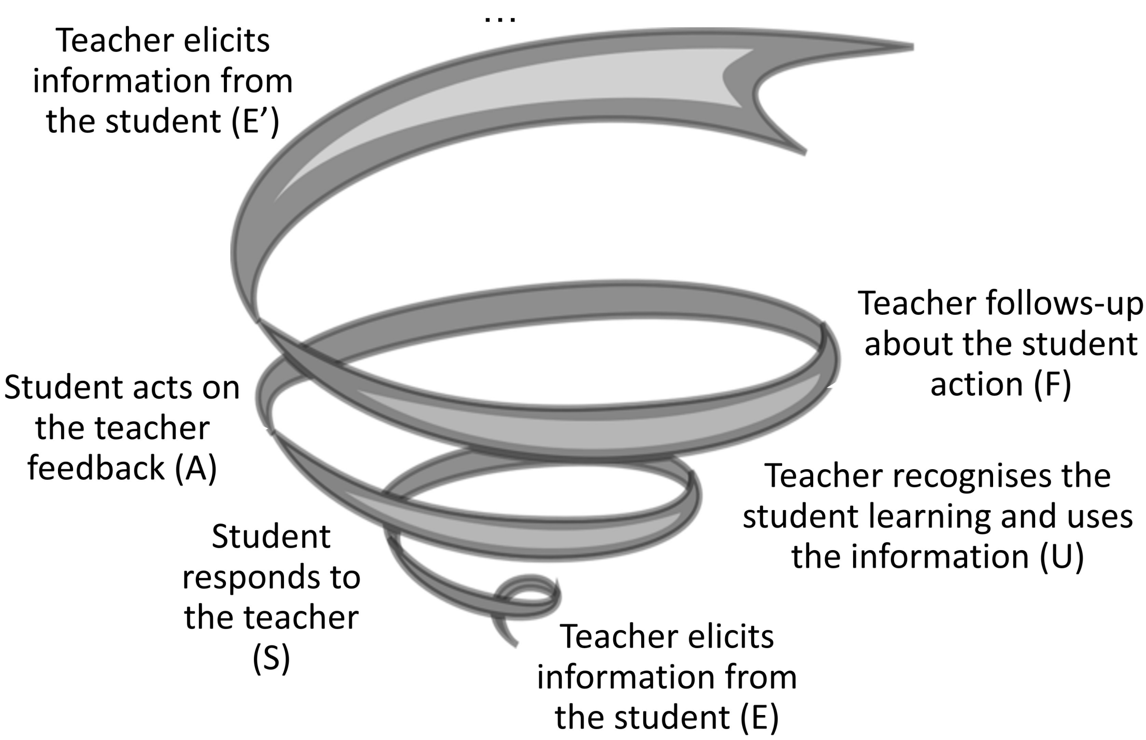
To illustrate the stages in this model, refer to the IFA dialogue between Sarah-Jane and Jay, Aria and another student is presented in Table 7.1. Sarah-Jane's dialogue with a group of students has multiple turns of conversation. Sarah-Jane waits for the students to explain why they used two bottles. In response, the students rethink their design and come up with a new design that requires only one bottle. They explain why - they felt two bottles could be a problem to connect – which was a problem other group of students who used two bottles in the classroom faced later in the making process. Thus, rethinking about an aspect of their design helped them produce a successful outcome. Sarah-Jane's habit of following up with the students in the classroom had created a culture where students acted on the feedback and/or come up with a logical defence of their design plans.

In the Table 7.1, subscripts with each letter show how the teacher elicits responses on multiple aspects of the design. After the first elicitation (E1), a student responded with response R1. The teacher seemed to accept the explanation about the design overall and used the explanation to elicit a specific aspect of the design (E2). As she got no response from the students, she asked them to think and discuss this aspect (U2). In the students' lack of response, Sarah-Jane recognised that they needed time to think more to be able to provide their reasoning. After waiting for some time, the students explained their modified design. Sarah-Jane followed-up (F2) about her specific question on the use of two bottles. The student explained their action (A2). In this sequence, it may seem that the student action is subsequent to the follow-up from the teacher. However, the students' acted first by changing their design and then the teacher followed-up about their change in design. It is likely that the students had not worked on that specific aspect of the design and answered the teacher's specific question. In that case, the teacher is likely to follow-up, the student does not respond, and teacher gives them more time to think/research. The stages go between follow-up and action until the issue is resolved. However, in following-up and being persistent on the single question,

Table 7.1
Further analysis of IFA dialogue between Sarah-Jane and some students

Dialogue in the classroom	Stages of IFA
Sarah-Jane: Tell me how this (their plan for water filter) works.	Sarah-Jane elicits information (E1)
Student 1: So, we are going to put some net here, then charcoal, then pebbles, then coffee filter and a bit of wool. So water falls through the net and then charcoal will purify it, then it will go to pebbles and then it will purify it more. Then it will go to the coffee filter. Then we will cut that off and (inaudible).	Student responds (R1)
Sarah-Jane: So why do you need two bottles?	Sarah-Jane elicits information (E2)
Students mumble and discuss but do not give an answer.	
Sarah-Jane: Go discuss that part of your design and come back. You have three minutes to discuss.	Sarah-Jane uses (U2) the information that students are not clear about their design and suggests they discuss amongst themselves
After eight minutes	
Sarah-Jane: (Calls them to her table)	Sarah-Jane elicits (E3) information
Student 1: We are going to cut up the bottle and then going to put it here, here, and here (indicating it in a drawing). Put a hole in here. We will put charcoal here and then some net. Then some pebble and then some more charcoal. Then we are going to put some more here and then some more sand and charcoal at the bottom.	Students explain the revised design (R3)
Sarah-Jane: So why have you chosen this order?	Sarah-Jane elicits (E4) information
Student 1: So charcoal can clean the water and pebbles can clean some more	Students explains their design (R4)
Sarah-Jane: So why do you have two layers of charcoal?	Sarah-Jane elicits (E5) information
Student 2: To purify faster. The more the layers of sand and charcoal, the faster the water will purify.	Students explains their design (R5)
Sarah-Jane: Why did you take out the second bottle?	Sarah-Jane is following up on her question on the two bottles (F2)
Student 2: One bottle will be better because two bottles will be harder to connect.	Student explains their action (A2)
Sarah-Jane: I am happy for you to make this.	Sarah-Jane asks them to proceed (U6)

Figure 7.2
Extended IFA model as a spiral



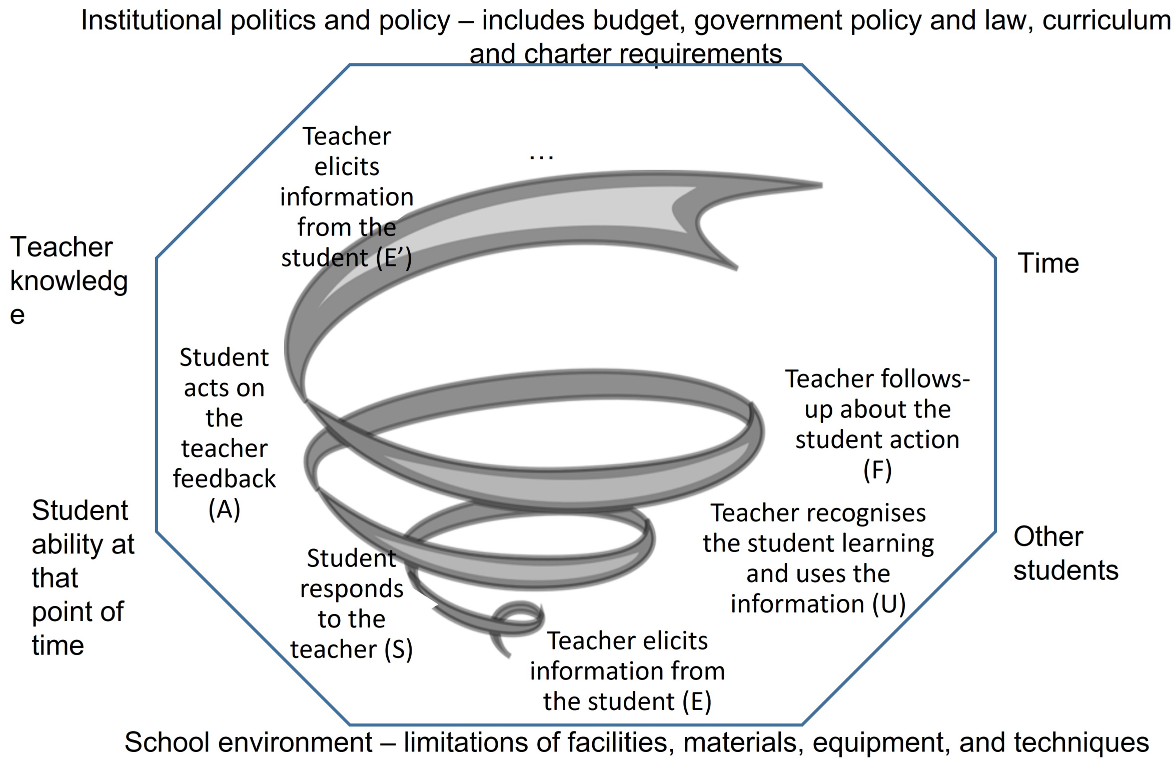
the teacher helped the student with their learning on that issue. Lack of uptake of the feedback could be an indicator of something deeper and teachers may need to decide if they need to provide more support or additional experiences.

Form of the model

Any IFA will be guided by the objectives derived from the subject curriculum AOs and the teachers' priority objectives for the classroom. The teacher could keep asking questions - one question leading to new learning and that could lead to more questions and more learning. As with many technology developments, where there is potentially no end point for the design of a product, IFA between the teacher and students for many goals within the process, could, theoretically, be infinitely long. Recognising student growth and offering support for further growth implies that the student does not go back to their starting point. Hence, the IFA in TE looks more like a spiral than the cycle depicted in literature. Figure 7.2 shows the model of IFA in TE as a spiral and the various stages of the IFA process.

Although the spiral is infinitely long in theory, in the classroom, different constraints

Figure 7.3
Proposed model of IFA



place an endpoint to the spiral. In some instances, the spiral is restricted due to resource or time constraints in the classroom. Teacher knowledge is another limitation to the potential of an infinite spiral of IFA. The spiral could also be restricted due to priorities set by the school, community, and the institutional politics such as methods of teaching, expectations of external, standardised tests, class size, out-of-classroom visits. Many of these constraints are the same as the constraints of technological practice in schools identified by Fox-Turnbull (2006) in her study. Additionally, the spiral could also be restricted by student ability at that point of time due to limited background knowledge to build on, limited ability in performing a specific task, or constraints due to levels of student interest and motivation. The needs of other students in the classroom could also stop teachers from asking more questions to a certain student group. Hence, the model of IFA in TE proposed in this study is a spiral with the limitations by constraints included, as shown in Figure 7.3.

Based on the proposed extension of the model, teacher follow-up may be critical for completing the IFA process. It has been mentioned that it is difficult for teachers to hold all the information in their heads and ensure that each student has progressed on all the learning goals in the classroom. To add follow-up to that mental checklist is not specifically helpful for teachers. In the following section, I discuss some ways that follow-up can be made easier.

Follow-up in Interactive Formative Assessment Model

I believe that adding more on the plate of an overloaded teacher is not a useful or actionable suggestion. However, on digging deeper into data and literature, I recognised that there was a way to make follow-up an easier process for the teacher that is, to develop students' capabilities to self-regulate (H. Andrade, 2010). Self-regulation is defined as "*an active, constructive process whereby learners set goals for their learning and then attempt to monitor, regulate, and control their cognition, motivation, and behavior, guided and constrained by their goals and the contextual features in the environment*" (Pintrich, 2000, p. 453). This definition explains that through self-regulation, students attempt to monitor their own learning based on the context of the classroom. Academic self-regulation is learnable (H. Andrade, 2010).

One example of self-regulation strategy that Jean used was to use a '*mahi-tahi*' sheet where all student names were mentioned in one column and the students had to tick off the different stages they had completed to produce their technological outcome. Figure 5.5 shows the *mahi-tahi* sheet from one of the units in Jean's classroom. At some point during the week, Jean could easily glance at the sheet and see which students were lagging and needed extra help to finish off their tasks. The sheet also helped the students know the different stages of producing their outcome and they could monitor their own progress.

In Sarah-Jane's classroom, students regularly came back to her in order to respond and update her regarding unfinished tasks or questions she had asked of them. For example, when Ana and her two group-mates were asked to research about how charcoal works in the water-filter, they returned to Sarah-Jane of their own volition once they found the answer. Ana and her group were practising self-regulation when they were proactive about their learning.

Some students show self-regulation strategies and behaviours without being taught. For example, at Athena, when Ria and Harper came up to the teacher with a solution to add sharpener to their pen holder in the cardboard unit (discussed in dialogue available at Section 6.3.3). Jean did not prompt them to come up to her. Similarly, once Ruby, Mila, and Ava decided to make the dollhouse, they did not need Jean's help in any aspect of their production of the doll house and they remained engaged and came to Jean for any problems they had without prompt from Jean. In the fabric unit, Emily and Brooke proceeded to design and make fabric bags with little input from Jean although they had remained passive in the previous two units and had to be prompted for brainstorming and developing their technological outcome. This finding supports the literature which states that students show capacity for self-regulation when they are motivated and interested in the technological outcome they are developing and have some assurance of success in their efforts (Efklides et al., 2017).

Thus, teachers can reduce the need for follow-up by teaching self-regulation strategies to students. This can reduce the burden of teachers carrying around information in their heads. Information that teachers learn during IFA is ephemeral (B. Bell & Cowie, 2001). Research also found that the formative assessment practices of the teacher is difficult to inculcate (Z. Yan et al., 2021). The next section seeks to explain why this could cause teachers difficulty in IFA.

7.1.2 Complexity of IFA

Literature says that IFA is a complex process (C. Harrison et al., 2018). However, there is no explanation of why IFA is complex. In an attempt to unpack the IFA process, refer to the IFA dialogue between Sarah-Jane and Jay, Aria and another student presented in Table 7.1. This table analyses the data differently than that done in the findings chapter in order to scrutinise IFA dialogue turns. Sarah-Jane seeks five different elicitations in a single dialogue lasting a few minutes. The five different elicitations were about the plan for the filter, the need for two bottles in the design, the changes in their design, the reasoning behind the order of the components in the filter, and reasoning for volume of charcoal used in the design. To situate those in TE, these five elicitations refer to learning around the properties of the materials in the design which belongs to the strand on TK and the component Tp, the plan for the design which is from the strand TP and the component ODE. The five elicitations were aimed also to promote critical thinking about the design. Sarah-Jane did not want the students to use all the materials without reasoning and wanted the students to deliberate on all aspects of the design.

As the elicitations from the teacher related to different learning goals – both in TE and behaviours – each elicitation could lead to a longer dialogue based on the learning goals identified for the group. For example, the question about order of components could have led to conversation about what would happen if the order changed, or some specific component was added/omitted. The question about charcoal could have led to a talk on the properties of charcoal and how it works – a learning goal that Sarah-Jane pursued later in the unit. Similarly, it would be possible to have a similar dialogue about the other components like pebbles, coffee filter, or sand. The question about the bottles could have led to a dialogue on plastic bottles and ways to manipulate them for specific outputs or other materials that could have served as well. Thus, each elicitation had potential for other deeper dialogue on different learning goals. Teachers have to make on-the-fly decisions about the student responses and what to emphasise in the students' response, what to focus on, and how to lead the student(s) towards the identified learning goals (Black, 2009b; C. Harrison et al., 2018).

Sarah-Jane asked these questions to a group of three students. She, sometimes, asked a specific student to answer some of the questions. Her knowledge of the students led her to decide on which student needed to respond to which answer. From analysis of all her dialogues in the classroom with all student groups, Sarah-Jane differentiated based on how the questions were asked. Sometimes, she asked the group if each student understood what the group was doing and sometimes, she asked them to explain to each other. The responses from the students could be verbal or non-verbal such as shaking of the head. Sarah-Jane, thus, seemed to be monitoring the learning spiral for each student through the questions. However, all this information the teacher is gathering is ephemeral in nature and not always recorded. The transient nature of IFA is mentioned as drawback of this method of formative assessment (Jordan & Putz, 2004). When Sarah-Jane was asked how she used all this information, she responded that it was in her head and she had to formalise it in student management system later. Teachers keep this information in their "head" and retain the information until they have need to formalise it. Jean responded similarly when I asked her the same question. Thus, teachers manage the information about multiple spirals of learning goals for multiple students in their heads. These teachers could also have different learning goals for different students for differentiation adding to the complexity. The complexity inherent in managing multiple spirals of learning for each student could explain why IFA is a complex process (C. Harrison et al., 2018).

Due to the transient nature of the IFA, teachers possibly retains a collective impression of the students' learning. Most likely, teachers note their impression based on the last few interactions but some specific information collected on learning for each learning goal may be lost and never noted down. It may not be necessary to record all this information, however. The purpose of the IFA is to progress student on their learning and the teachers' using (U) the information through giving feedback at that moment helps the student with their learning. Hence, it is necessary that teachers follow-up on the feedback. However, teachers enacted practice is affected by their beliefs and knowledge. These are discussed in the next section

7.2 Impact of teacher's beliefs and knowledge on Interactive Formative Assessment in Technology Education

This section aims to respond to the research question "*How do teachers' beliefs and knowledge impact Interactive Formative Assessment in Technology Education?*". In Section 2.2.4 of literature review, I discussed the various research studies as well as theoretical positioning of the two concepts of teacher beliefs and teacher knowledge. Knowing that the two of them have an impact on teacher's enacted practice, the interview questions were designed to include this information. The results were reported in Section 5.1. This section then aims to analyse teacher beliefs and knowledge separately in light of the findings and literature. Teacher beliefs are split into two sub-sections: teacher beliefs about teaching and learning and teacher beliefs about importance of TE. These are followed by the two sub-sections of teacher knowledge: teacher's content knowledge and clarity of learning intentions. The next sub-section relate to the use of QFT-P and how it enhanced teacher practice and finally the problems in changing teacher practice.

7.2.1 Teacher's beliefs

Teacher's beliefs about teaching, learning, conceptions of the subject, nature of the subject are said to have to an impact to the teacher's practice in TE (Dakers, 2005; Doyle et al., 2019; Jones et al., 2013). Teacher's belief and knowledge about TE can cause them to focus on the end product rather than the thinking skills, creativity, processes, issues and key learning (Jones et al., 2013). In this section, teacher's beliefs about teaching and learning and teacher's belief about TE are discussed in two separate sections.

Teacher's beliefs about teaching and learning

As discussed in literature review, teacher's beliefs about teaching and learning can have an impact on how they plan their lessons and organize the classroom (Fives et al., 2015). Teacher's beliefs about teaching and learning, in research, mainly translate as teacher-centred classroom or student-centred classroom (Fives et al., 2015). However, Fives et al. (2015) urged researchers to define and explain the terms they use clearly. In an attempt to be clear about the classroom and not use generic terms, I do not use teacher-centred or student-centred classroom and instead describe the teacher beliefs and practice in detail.

In this study, during every lesson, across the different stages of the unit, both teachers had dialogue and facilitated discussion with students. In reviewing the literature on classroom talk, it was indicated in multiple studies (and summed up in meta synthesis by Howe and Abedin, 2013) that teachers tend to dominate classroom talk and classroom talk is mostly non-interactive. Multiple researchers have also pointed out the difficulty of implementing dialogue in the classroom (Davies et al., 2017; Reznitskaya et al., 2009; Reznitskaya & Wilkinson, 2015). However, in contrast to the literature, the teachers in this study rarely dominated the classroom conversation and their lessons were interactive. The success of the two teachers in having interactive lessons is likely a result of their beliefs about student voice.

Teacher beliefs have been linked to how teachers implement assessment in the classroom and teacher decision making in classroom interactions (Buehl & Beck, 2015; Helms, 1998; M. F. Pajares, 1992). Schoenfeld (1998) in his seminal work asserted that teacher's on-the-fly teaching decisions are a function of teacher's goals, beliefs, and knowledge. Reznitskaya and Wilkinson (2015) and Wilkinson et al. (2017) emphasise the critical nature of a teacher's belief in implementing dialogue based practices in the classroom. In this study, both teachers mentioned that they believed in students communicating and collaborating with each other rather than being lectured to. Both teachers believed themselves to be facilitators of the students' learning. A research study by Correia and Harrison (2020) concluded that teachers who believe in being facilitators tend to have more classroom discussion and dialogue. It is important to note that the teachers' beliefs could be why they agreed to be part of this research study because its methods and purpose aligned with their beliefs in the importance of student talk in the classroom.

As the teachers believed in the importance of student voice in the classroom, they engaged students in dialogue and asked them questions about their learning – in whole class discussions, in small groups, and individually. Through multiple dialogues, the teachers were able to ascertain where the students were in their learning and could offer guidance for students to progress further. Both teachers viewed student contribution as providing important information for assessing developing understanding, progress, and achievement in the curriculum subject area. In this study, both teachers believed in the importance of questioning students and listening to the responses carefully. The two teachers' beliefs about the importance of student voice in the classroom made the use of the QFT-P easier and consequently, their IFA practice.

Teacher's beliefs around Technology Education

Teacher's conceptions of the subject are critical in how they organize the lesson in the classroom (Dakers, 2005; Doyle et al., 2019; Jones et al., 2013). Specifically, the teachers' understanding of technology, TE, importance of TE is quite important.

Both teachers defined technology in line with the definition given in NZC and did not imagine TE only as computers. Both teachers believed that teaching reading, writing, and maths could not be the only priorities in the classroom. From 2010 to 2019, National Standards of curriculum policy was imposed on primary classrooms in NZ that focussed on reading, writing, and maths (Fox-Turnbull et al., 2021). The resulting high stakes assessment associated with this policy in these areas saw a narrowing of school curriculum. In both schools, the reporting system for the *whanau* (family) was reporting reading, writing, and maths scores. Despite these pressures from the school and policy context, the teachers' beliefs stood in opposition. School contexts and government policy has been seen to impact teacher's practice and it can lead to incongruity between their beliefs and practice (Buehl & Beck, 2015; Doyle et al., 2019). However, at least the teachers' stated beliefs and their planning of lessons other than reading, writing, and maths were in alignment.

However, despite this alignment, Jean mentioned in the final interview that she did not have enough time to focus on dialogue on TE with all students and also do maths and reading. This contradiction in belief systems in not uncommon. Teachers hold opposing beliefs and it is likely that in different contexts, differing beliefs dominate (Skott, 2015). Research also shows that inexperienced teachers often show incongruity between beliefs and practice as their beliefs are in flux (Buehl & Beck, 2015). Jean had three years of experience and was an inexperienced teacher. She was new to doing an integrated PBL unit. Considering the new experiences of teaching and planning, it is likely that her beliefs were in flux and lead to some inconsistent practice.

At Minerva, Sarah-Jane mentioned how she had to fight to get half a day a week to focus on science, technology, and arts. The school did not provide many resources for Sarah-Jane to do TE. Although no incongruity was noticed between Sarah-Jane's practice and beliefs, the added pressure from the school and lack of resources could possibly limit her STEAM practice. When a teacher's accountability is limited by pressures from outside, their creativity, control over their teaching methods, and development of their skills is restricted (Black, 2018). It could also lead to burnout and teacher's quitting the school or profession when teachers are forced to work in opposition to their beliefs (Buehl & Beck, 2015).

In conceptualising the role of TE in PBL and STEAM, the teachers' beliefs about TE can play an important role in how they create interest in the students in the subject. While Sarah-Jane worked hard to ensure that she could teach TE through STEAM, her belief that STEAM was "bigger than" TE could have led to her seeking out STEM/STEAM resources online and STEM/STEAM communities rather than the TE resources or community. Similarly, Jean and her primary team's focus on PBL along with the school's reporting of literacy and numeracy meant that Jean focused on literacy and maths integration in PBL with limited focus on TE integration. The two teachers did not seek out TE resources such as the Technology Online website, the technology curriculum document, and TE communities like TENZ despite knowledge of their existence. Teacher's need support to implement subjects in line with their beliefs. Lack of support in integrating TE in these approaches could lead to an incongruity in the teachers' beliefs and practice (Chen et al., 2015).

Within the TE community, there is concern for how the emerging preference for STEM, PBL, focus on digital technology will impact TE. There is some cause for celebration based on the evidence from this study. Teachers with limited knowledge of TE but an interest in PBL/STEM can support students' growth in certain components of TE. However, there is also evidence from this study that without strengthening the status of TE with these approaches, student growth in TE is likely to hit a ceiling. The next section discusses the teacher's knowledge

7.2.2 Teacher's knowledge

Teacher's knowledge, like teacher's beliefs, is difficult to define. In Section 2.2.4 of the literature review, a brief review of teacher knowledge was provided. In TE, Doyle et al. (2019), in a model for reconceptualised PCK for TE, states three types of knowledge for TE teachers. These are: PCK, topic specific professional knowledge, teacher professional knowledge bases. Based on Consensus Model of PCK (Gess-Newsome, 2015), Teacher Professional Knowledge Bases consists of assessment knowledge, pedagogical knowledge, content knowledge, knowledge of students, and curricular knowledge. Topic-specific professional knowledge includes knowledge of instruction strategies, content representations, student understanding, subject practices, and habits of mind. PCK could include students' concept of technology, knowledge of pupils' pre and misconceptions, knowledge of pedagogical approaches and teaching strategies for TE (Rohaan et al., 2010). Rohaan et al. (2010) also suggests addition of attitude which includes the aspects of attitude towards teaching technology and confidence in teaching technology to teacher's knowledge. As the main focus of the study was not to study teacher's knowledge, only some of the knowledge was studied. Content knowledge is proven to have a positive effect on teacher's PCK as well as efficacy in TE (Rohaan et al., 2012) and on student outcomes in science (Gess-Newsome et al., 2019; Sadler et al., 2013). Based on research data, the focus of the next two sections is to discuss teacher's general content knowledge and in clarity of learning goals for each lesson.

Teacher's content knowledge in Technology Education

Content knowledge includes knowledge about the knowledge of the subject and its conception. The two teachers' understood TE as "*intervention by design*" in line with how the NZC defined TE and the teacher's understanding of TE influences how they approach the subject. In the initial interview, the two teachers drew TE as an iterative process in the classroom (Section 5.1.2) – demonstrating that they needed to give students an opportunity to experiment and trial their development of technological outcome. Both teachers also knew that "technology" was not only modern technology like computers but was any technology that was designed for a specific purpose.

Despite a basic understanding of definition and process of TE, Jean demonstrated limited content knowledge about some of the TE terminology. Sarah-Jane, on the other hand, used TE terminology more confidently in the interviews with me but the translation of this knowledge in the classroom was limited. In an interview when Jean was asked to evaluate the student products, she could clearly figure out the attributes of the product that she could use for evaluation. In the classroom, while reading a TE based article, she explained to the students why product evaluation was necessary. However, none of this knowledge was transferred while she was executing her TE lessons. In fact, until I interviewed Jean, she did not realise that she already had all the TE knowledge regarding attributes and outcome evaluation. A possible explanation for why the teacher's TE knowledge might not get recognised and translated into classroom use could lie in the theory of implicit knowledge.

Implicit knowledge refers to the knowledge that a person acquires in a complex stimulus environment without an intention to acquire the knowledge and without being able to express the learning (Berry & Dienes, 1993). When asked questions about the knowledge, few people are able to recall and articulate how they learnt something and are not able to recall the knowledge without any prompts (ibid). Implicit knowledge is robust but also difficult to transfer to related situations (Dienes & Altmann, 1997). As technology is all around us, we are frequently exposed to technologies. It is likely that everyone implicitly learns about technological outcome attributes, the role of technology in our daily lives, relationships between technology and society, use of sketching to represent ideas, modelling and its benefits, applications of different models to different needs, and materials and their manipulation. However, it is likely that this implicit knowledge cannot be recalled easily in a different situation or in solving problems in a different environment.

Teachers, who are exposed to technology as consumers, likely learn and classify these different exposures as related to technology that they encounter in their lives and media and possibly do not connect it to their experiences of teaching TE in the classroom. On being given cues through questions in the interview, the teachers in this study could verbalise some of their implicit knowledge. Implicit knowledge can be retrieved and applied on being provided cues (Dienes & Altmann, 1997). To make implicit learning explicit, reflection sessions will need to be conducted that operationalises the knowledge about technology that the teachers are not even aware of possessing. In this study, the interviews with the teachers, unintentionally, acted as reflection sessions. Professional development conducted in a dialogic style would support teachers to draw on prior experiences with various technologies and cultural references about technology from their exposure to daily media. Teachers can then link their experiences to the technology curriculum. Cues provided through a dialogue are likely to make implicit knowledge about technology, explicit.

Teachers with limited content knowledge about the subject they are teaching tend to ask fewer questions (Newton & Newton, 2001). While the teachers in this class asked a lot of questions, there were still missed opportunities against the TE curriculum document for both the teachers. These missed opportunities were around creating a list of attributes, evaluating the technological outcome against attributes, progression in 2D sketching, modelling for Jean. For Sarah-Jane, missed opportunities were around progression in 2D sketching and use of technology terms.

Any observed lesson with any teacher would have missed opportunities and it is difficult to qualify the missed opportunities as a deficiency in content knowledge. In a study by Enyedy et al. (2006), a teacher who was student centred compensated for their lack of content knowledge in science through their commitment. Jean displayed this kind of compensation when she re-designed the technical drawing sheet to include details about joints (see Figure 6.10). It is possible that as the teachers conducted more TE units, they would be able to compensate for more of the gaps in TE content knowledge. Teachers learn in dialogue with students. Such conversations where both teachers and students are learning have been termed as divergent intercognitive conversations by Fox-Turnbull (2016). However, this method of technology content learning is likely to take several taught units of technology by the teacher. Targeted in-service professional development may hasten this learning process and is part of recommendations in Chapter 8.
It is to be noted that both teachers, in this study, were able to use the QFT-P without additional professional learning. The reason for their ease of use could be because of their understanding of TE. However, both rated their own confidence of teaching technology against the curriculum documents as four out of ten implying that they did not feel confident about teaching TE as per NZC. Their self-efficacy in teaching TE could have hampered how they approached TE in the classroom as well as which questions they

chose to ask in the classroom. However, in Section 5.2.3 in Findings, it was reported that by using the QFT-P, Jean expanded her notion of technology. Using the QFT-P for two units improved Jean's self-reported confidence in teaching TE. Sarah-Jane reported that she learnt about what more she could include in her teaching of TE. Thus, both teachers' content knowledge was affected by the use of QFT-P and their dialogue with students and this relationship was reciprocal. Besides general content knowledge in TE, teachers need to have clarity in their learning goals for each lesson, discussed next.

Clarity of learning goals

In order to conduct dialogue for formative assessment in TE, data from this study reaffirmed that clarity is needed in the learning goals for lessons in TE. In a study by Jones and Moreland (2005) found that teachers formative assessment practice in TE improved when they focused on specific concepts across the strands. In this study, when teachers were able to select the question from the QFT-P based on the learning goals for that specific lesson in TE, they had more effective dialogue. For example, when Jean wanted students to make a creative design that had a purpose besides being decorative, she followed up every student explanation with "*What is the purpose of this design?*" and sometimes with the feedback comment "*This is not creative enough/This is a bit safe*". Sarah-Jane had a clear learning intention of having students explain the purpose of each layer in the water-filter unit when she followed up the students' replies with "*Why have you put stone above the sand?*", "*What does charcoal do*?", "*Why did you choose this order?*". These interactions provided the teachers reasoning and insight behind students' actions and provided information that they could use to make formative assessment decisions and guide the students further, if needed.

Multiple researchers agree that effective IFA is required to be guided by learning goals (Furtak et al., 2017; Moreland, 2003a; Ruiz-Primo, 2011). This study also had examples of absence of dialogue when the teacher did not have clear learning goals in mind. For example, when the students were making their models, Jean confessed that she did not know what conversation she could have with the students. During the making phase, Jean had fewer dialogues or discussions with all students in comparison to the brief development phase. In this classroom, not having a clear learning goal for the making phase led to little opportunity for dialogue for the purpose of formative assessment. The teacher could, in turn, then offer limited support to student learning in the making phase of the TE practice. Clarity on the learning goals in every phase of the TE practice is, thus, essential for teachers to be able to conduct dialogue for purpose of formative assessment in the TE classroom.

7.2.3 QFT-P as an enhancer to IFA

The QFT-P served as a tool for the teachers to conduct IFA in the classroom. Through using the QFT-P and listening to student answers', they participated in deep dialogue with the students. The dialogue was intercognitive in nature - the teachers learnt about student learning and students learnt about TE and other priority objectives in the classroom. QFT-P can enhance IFA for teachers. Based on the teachers' input on the QFT-P and the audio analysis from the classroom, the QFT-P did help them ask questions that they had not asked before in their TE classrooms. This study has offered evidence for the additional advantages of the QFT-P. QFT-P provides good questions in TE to teachers as recommended by educators in formative assessment (for example, Black, 2008). The use of the QFT-P also leads to other benefits such as improvement in teacher content knowledge as can be seen from this study and a previous study by Fox-Turnbull (2018). Dialogue with students for IFA can lead to other benefits mentioned in literature such as better conceptual learning (Applebee et al., 2003; Howell et al., 2011; Miller et al., 2014; Murphy et al., 2009; Reznitskaya et al., 2009; Wegerif et al., 1999) and increase in engagement (Chinn et al., 2001; Jay et al., 2017; S. Ma et al., 2017; J. Zhang et al., 2013).

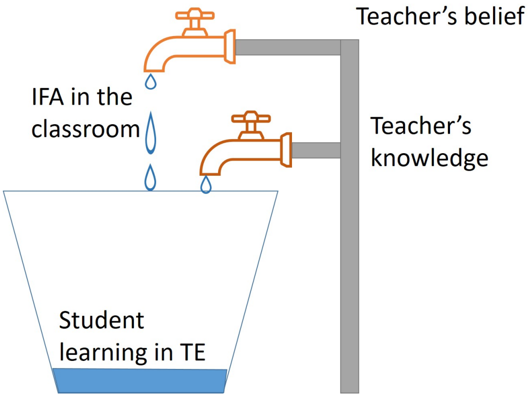
Teacher's beliefs and teacher's knowledge set the stage for IFA. As teachers believe in the importance of student voice in the classroom and in the importance of TE in whatever their approach to teaching, they are likely to make space for TE in their classroom. Teacher's content knowledge of TE and clarity of learning intentions for TE lessons can help teachers conduct IFA in the classroom that will, in turn, improve student outcomes. Teacher's beliefs and knowledge are not binary. They are not present or absent. They can be present at varying levels. I conceptualise them as water taps that fill up the bucket of student learning in TE. Absence of any of the 'taps' means that the bucket does have some water, but it is low, and the teacher is likely to take long time to recognise student learning in the classroom and student learning in TE is filled slowly. This scenario is represented by Figure 7.4a. QFT-P can be thought of as an enhancer to IFA. In this analogy, QFT-P works as a pump. It enhances the water flow and the bucket of student learning fills faster. This scenario is represented in Figure 7.4b.

QFT-P can help the teachers focus their IFA on TE objectives. Both Jean and Sarah-Jane indicated, some of the questions from QFT-P were familiar to them and they have asked such questions in the classroom prior to participation in this study. The familiarity adds to comfort with using QFT-P. It is likely that more experienced teachers will know many of the questions from the QFT-P and will be able to conduct IFA with minimal input from QFT-P.

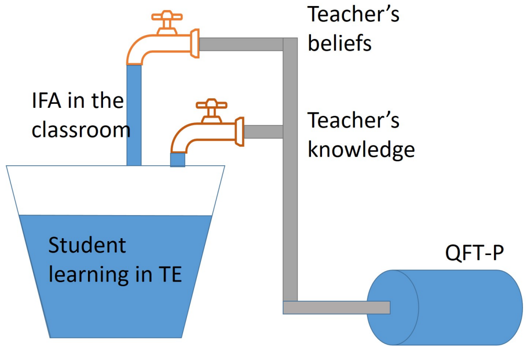
Figure 7.4

Analogy to demonstrate relationship between teacher's beliefs and knowledge and IFA

(a) *Teacher's beliefs and knowledge and IFA*



(b) *QFT-P as a pump enhances IFA and student learning*



When teachers, like those in this study, believe in the importance of student voice in the classroom and have limited knowledge in TE are given the QFT-P, and the teachers ask questions from the QFT-P, the resulting conversation may not always lead to concrete learning experiences for the student. The effect of IFA is uneven and diffused in those lessons. When teachers in a traditional classroom that is more teacher-led undertake IFA, the QFT-P can still provide a framework of questions for the TE teacher. QFT-P would be used in the traditional IRF pattern of conversation. IRF stands for Initiation-Response-Feedback pattern that is known to produce brief responses from the students. Lack of dialogue in the classroom could still lead to some IFA – but the teacher is likely to guide students to the learning goals in a pre-determined or a prescriptive manner. The QFT-P can be a useful tool for formative assessment in many scenarios with teachers of differing beliefs and knowledge. However, they may not see all the benefits of using QFT-P.

7.2.4 Teachers changing practice

It is difficult for teachers to change practice as there is a complex relationship of practice with beliefs, knowledge, and self-efficacy (Skott, 2015). In this study, I found Jean struggled with changing her practice despite an alignment with her beliefs. Early on Jean was exposed to the many questions of QFT-P at one go and struggled to review them and use it extensively in the classroom. In contrast, Sarah-Jane asked for only a few cards at a time and was able to peruse them multiple times and use the questions frequently during the lessons. The extended format of the initial version of QFT-P likely caused Jean's difficulty in selecting questions for use during her lessons. Jean mentioned that she did not invest time in reviewing the questions from the QFT-P during the planning time. Jean's reluctance is common for any teacher when they seek to incorporate new practices in the classroom (C. Harrison, 2013). While it is likely that the overwhelming number of questions caused her reluctance to invest, another layer of reluctance could have been driven by her relative inexperience as a teacher impacting on her confidence in the research situation. Any pedagogical change is difficult for teachers, especially in the area of assessment (Hargreaves & Fullan, 2015; C. Harrison, 2013). For Jean, who was relatively new to the school and PBL, she was constantly learning to work with her colleagues in the primary section and collaborate on the PBL projects. Her lack of experience in PBL projects or TE, meant she was constantly learning. Due to the relative newness of every aspect of her classroom practice, it is likely that she experienced a high cognitive load that made any additional learning quite difficult.

According to the cognitive load theory, first proposed by Sweller, van Merriënboer, and Paas (Van Merrienboer & Sweller, 2005), in order to convert learning into the long-term memory, information and knowledge is processed in the working memory. However, working memory is limited and any load beyond the capacity of working memory cannot be processed (Sweller et al., 1998). Knowledge is arranged as schema in the long-term memory (ibid). Once knowledge has been arranged into a meaningful schema in the long- term memory or attached to other schema in the long-term memory, we are said to have learnt it and this learning reduces the load on the working memory (Sweller et al., 1998). As the schema are recalled and repeated multiple times, automation is achieved and further reduces the load on the working memory (ibid). To take a simple example of learning driving, the novice learner must first learn about the mechanics of the car – about the gears, the brake, and the accelerator. Actions involving these features of a car preoccupy the new driver's attention. As the learner gets familiar with basic mechanics of starting, stopping, increasing the speed, and steering the car and gains automaticity in handling the car, the learner starts to notice the road conditions and is able to learn about responding to the traffic, pedestrians, and road rules. The novice slowly gains expertise and soon the act of driving becomes almost automatic.

In a classroom, the cognitive load theory may explain how a novice teacher in the classroom is at first unable to process the multitude of complexities of a classroom – including but not limited to classroom management, lesson planning, knowing the students and their background, planning for differentiation and scaffolding, planning assessments, handling administrative tasks of a classroom, being part of a bigger team at the school, and engaging with parents/ guardians. As the teacher spends more time in the classroom and some of the new tasks get automated, and others are learnt, the novice teacher slowly builds automaticity in other tasks until she is sufficiently expert in most of the daily decision making that the teacher faces. As Jean had relatively little teaching experience and was a new teacher at this specific school which taught in a format that was completely new to her, it is likely that her working memory was quite full and she felt unable to add on the reading of QFT-P to her list of priorities especially as the QFT-P was designed for TE in which she did not feel confident.

In this section, I discussed the role of teacher beliefs and knowledge on their TE practice. I further discussed how QFT-P could work as an enhancer to IFA and hence, student learning in TE. I proposed cognitive load theory as an additional barrier for teachers, especially, inexperienced teachers, to change their practice. In the next section, I focus on student learning.

7.3 Influence of IFA on student learning

This section focusses on responding to the third research question "*What influence does Interactive Formative Assessment have on student learning in Technology Education?*". The findings offered evidence that student learning was demonstrated for technology curriculum objectives and teacher's priorities that are grounded in the key competencies of the NZC. Student learning was demonstrated through analysing dialogue that began with questions from the QFT-P in the classroom for most objectives except for the technology objective on modelling (2D representations) and the learning in design and visual communication at Athena, which was inferred through analysis of student sketches and final poster. Thus, most of the student learning was inferred from the analysis of discussion and dialogue in the classroom which implies the importance of student's voice in understanding achievement in TE in the primary classroom. There are two subsections. The first sub-section examines student learning against curriculum objectives, and the second sub-section discusses students uptake of feedback from the teacher-student dialogue.

7.3.1 Learning curriculum objectives

Evidence in this study affirms that teacher-student dialogue in IFA positively influenced learning in TE curriculum objectives and teacher's priority objectives. Specifically in technology curriculum, students demonstrated learning in understanding the brief, brief development using market research, modelling 2D representations of their technological outcomes, understanding relationship between properties of materials and the technological outcome, understanding influence of technology on the environment, and evaluating of technological outcome against the brief. Table 6.1 offers a detailed view of what was taught by the students against specific AOs of the technology curriculum in NZ. The data from the classroom is based on one unit of TE. There can be no assumptions made about the teaching and learning of all aspects of a AO. AOs in TE have multiple objectives. For example, the AO relating to component ODE in strand TP for Level 3 is "*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*". Within this AO, there are multiple aspects: investigating a context to develop ideas for potential outcomes, ideas to be trialled through appropriate modelling, deciding on the key attributes for the outcome, selecting appropriate materials, developing an outcome, and evaluating the outcome against key attributes and the need. It may not be possible to cover a complete AO in one unit. Hence, the evidence from this study about the AO is often about partial fulfilment of the AO and Table 6.1 highlights the part of the AO that the teaching were about.

In NZ there is no study to date that has investigated the teaching or learning of specific AO. The 2016 NMSSA, the monitoring study led by the Ministry of Education (Educational Assessment Research Unit, n.d.), tested Year 4 and Year 8 students against TE AOs. It was found that 73% students at Year 4 achieved level 2 and above (Educational Assessment Research Unit, n.d.). There is no more detailed breakdown of performance across the different strands. The report also found that most teachers estimated that they spent 50% of time on the strand TP. The dominance of TP objectives can be seen in this study as well.

Besides TE curriculum objectives, evidence was provided for teacher's priority objectives in the classroom that were grounded in the key competencies of the NZC. In relation to teacher's priority objectives, the findings indicated that students demonstrated learning with regards to working in teams and problem solving. Jean had a further objective of creativity and Sarah-Jane had an objective of developing reflection. However, there is not much evidence from the students about the development of these two objectives. Objectives such as creativity, reflection, collaboration, problem solving can not be taught and learnt in one unit. The development of these objectives takes time and continued effort needs to be made by the teachers to develop these skills. Besides concrete learning objectives, the findings showed that the influence of IFA on student work is complicated and difficult to unpack. The reason for unpacking the influence is due to students' uptake of the teacher's feedback.

7.3.2 Students' uptake of teacher's feedback

Teacher-student dialogue for IFA has an influence on students' uptake of teacher feedback. Results identified from data in Jean's classroom were detailed in section 6.3. Table

7.2 shows the four groups of students classified on basis of how many followed Jean's instruction to make their design more creative and their technological outcome.

Table 7.2
Summary of results of student technological outcome

Students not asked to change their design	Dev, Noah, Vijay,	3-in-1 foosball table, Beyblade stadium and safe
	Andy + 2	A robot (toy)
	Lucas, Sophie	A robot with storage drawer
Students who were asked to change their design but did not make the changes	Emily, Brooke	Minion (toy) to Car for minion (toy) [Suggested: auto powered car]
	Isla, Nicole	A fox shaped pencil holder [Suggested: Pencil holder with secret compartment]
	Olivia, George	Candy holder, action figure [Suggested: Action figure holding candy holder]
Students who were asked to change their design and changed their design	Ava, Mila, Ruby	Basketball court to Dollhouse
	Ria, Harper	Pencil holder to Pencil holder with in-built sharpener
Students who changed their outcome without consultation	Leo, Bao	Vending machine to Puppet stage
	Amelia, Willow	Basketball court game with jewellery box to Basketball court game and photo frames

Jean prompted her students to make their designs more creative by adding a moving part to their design. Analysis of the students' dialogue and output in the classroom provided some insight on the students' uptake of teachers' feedback. The possible reasons for students failure to implement feedback include providing appropriate feedback, a lack of scaffolding to act on the feedback,what is valued in the classroom, and psychological reasons relating to students. Each of these reasons are discussed in detail in the sub-sections.

Limitations in providing appropriate feedback

There are multiple reasons seen in the evidence for why teachers could not provide appropriate feedback. These are interruptions in the classroom, lack of time, and teacher's responsiveness during the dialogue. These reasons are interconnected. For example, teacher responsiveness could be hampered due to interruptions or multiple interruptions could influence the teacher's perception of time.

Interruptions in the classroom

The classroom is a complex environment and a dynamic place with teachers facing multiple interruptions. These interruptions can be in the form of other students needing resources or clarifications. Interruptions can also be triggered by what the teacher observes – if she finds students disengaged or doing something physically harmful. Interruptions can occur from outside the classroom like when students from other classes come to borrow resources or teachers from other classrooms need to talk to the teacher. The school administration can interrupt with important updates or for reminders. There could also be interruptions from parents. In this study, these interruptions impacted Jean's ability to provide appropriate feedback in two ways - she could not prioritise having extended dialogue with all students and her responsiveness when she was talking to the students.

There were some instances in the classroom where Jean was constantly interrupted during her dialogue with the students. Consider the dialogue Jean had with Dev and his group presented in section 6.3.1 with reference T1-Week3Day5-M1-2-min 1:50 (Click here for relevant dialogue 6.3.1). In the dialogue with Dev and his group, Jean spent almost six minutes talking to the group. She was interrupted three times in those six minutes. These interruptions were typical in Jean's classroom and lent credence to Jean's worry about having long conversations in the classroom with a group of students.

Lack of time

Jean was worried about not having enough time to talk to students about their learning. Jean felt that due to some students requiring extensive support in the classroom to carry out the tasks, she could not have extended dialogue with other students. Jean mentioned in an interview that she found it difficult to ask high-cognitive questions to one student (or one group) and listen and respond to their answers because she had so many other students in the class with different needs. She explained that she did not have time to have the conversation as she wanted to do it properly and not just ask a question and go away.

This lack of time for meaningful interaction has also been identified in other research studies. Some researchers (Lehesvuori et al., 2011; Scott et al., 2006) acknowledge that time could be perceived as a barrier for teachers to listen to student answers. Scott et al. (2006) state that teachers may not have enough time to listen to every student's response – a sentiment that agrees with the comment Jean made.

While Jean talked about time as a barrier to have extended dialogue with students, Sarah-Jane did not mention any concerns with time in the classroom for questioning students and was not interrupted as much based on analysis of her audios with the students. A key difference in Sarah-Jane and Jean seems to be the number of years of teaching experience. Lehesvuori et al. (2011) mentioned time as a barrier for pre-service teachers and hence, it is likely that teachers with fewer years of teaching experience could face time as a barrier for dialogue with students. While the study does not explain how time is a barrier, from observation it could be seen that Sarah-Jane was able to create a classroom culture where students did not interrupt her during her dialogue with other groups either from politeness, greater autonomy in the classroom, or preparation by Sarah-Jane with resources needed for the lesson. Despite having students with special needs in the classroom, Sarah-Jane did not mention those students' needs as a barrier to dialogue with other students. Analysing interruptions during teacher-student dialogue was beyond the scope of this study. Hence, it is difficult to conclude about the differences in the ways the teacher managed the classroom and its effect in how much dialogue the teachers are able to have with individual student or student groups.

Teacher's responsiveness during dialogue

Teacher's responsiveness to students' thoughts and conversation is critical to effective formative assessment that can guide the student to the next stage of learning (Gotwals & Birmingham, 2016). Partially, Jean's lack of responsiveness can be understood by analysing her dialogue with Dev and his group (Click here for relevant dialogue 6.3.1). In one instance of conversation, Jean asked the same question at least three times to Dev and his group before she could get an answer. Jean could ask two questions – repeated and rephrased multiple times. This constant repetition of the same questions could have distracted Jean from extending the dialogue even though the dialogue is likely to have provided the students with invaluable learning around listening to the customers.

Dev and his group planned to make a 3-in-1 product. From their answers, it is unclear that all three of them answered all the questions for each of their part of the technological outcome. Jean did not seem to recognise that each of them had a different technological outcome and had asked different questions in their market research. Hence, she should have expected three different sets of answers to the questions. Jean's limited responsiveness to the dialogue with the three students is likely to have caused the three students to struggle in developing their product and having a successful outcome. The three of them mentioned in their reflection that they did not have enough time to make a 3-in-1 product and struggled with creating a stable technological outcome.

In the final interview, Jean mentioned that while the dialogue with students was useful, but it was not useful enough to justify the investment in using the QFT-P. Beginning teachers struggle with responsiveness in the teacher-student dialogue (Athanases & Achinstein, 2003; E. A. Davis et al., 2006). Even when the teacher elicits student thinking, they may struggle to recognise the student learning and identify alternate conceptions or gaps in student reasoning (van Es & Sherin, 2002, 2006). Jean had taught for three years only and was teaching with a new approach. It is likely that Jean could not recognise the student thinking from their responses during the dialogue and therefore, felt that the dialogue was not useful for the learning process. It is to be noted that this section talks about specific instances where Jean may not have been responsive, but it is not characteristic of every dialogue that Jean had in the classroom.

Lack of scaffolding to act on the feedback

Some reasons for students' inability, in this study, to uptake teacher's feedback within the teacher-student dialogue for formative assessment, could be that they needed additional support to implement the feedback. Although, they were part of the dialogue where the feedback was given, it is likely that student(s) did not ask follow-up questions to understand the feedback properly or they could have had more questions later when they had time to think about the feedback. It is also possible that students do not make the changes if they do not correctly interpret the importance of the specific feedback given during the dialogue. For example, if during the dialogue, the conversation covered several different points, the student could focus on some other aspect of the discussion and "forget" other feedback. They could become distracted once they return to their worktable and lose focus on the important aspects of the discussion.

Brooke and Emily after Jean's initial suggestion to change from minion toy to something else, immediately came up with a car and spoke to Jean about it. Jean agreed with their design plan but asked them to make it a moving car. It is likely that these students could not figure out how to make their car move and hence, could not incorporate this change. In the first dialogue with Jean, Isla and Nicole were asked to think of something creative. This direction from Jean possibly seemed too vague. Next day, when Jean again challenged them to do something creative, they said they could make the mouth open and close and create a secret compartment. It is likely that they found this too difficult to implement because they did not incorporate this change. Grangeat et al. (2021) mention that students need additional support and guidance from the teacher when they are learning new ways of doing and learning. Scaffolding could help students make a more successful technological outcome. The stages of follow-up by teacher (F) and student action (A) have been added to the IFA model to ensure that cases such as Brooke, Emily, Isla, and Nicole get adequate support to implement their ideas.

The findings from this study offer evidence that if the students do not implement the feedback within the next lesson, it is unlikely that the feedback will be acted on. It can be seen in all the cases in both the classrooms. Emily and Brooke made their change from minion to minion car in the same lesson after receiving the feedback. Ava, Mila, Ruby, and Willow changed their design by the next day. Ria and Harper spoke to Jean the next day with their design plan for putting a sharpener in their design after Jean's feedback. Hence, any feedback was acted upon within the next day. Sarah-Jane followed up with all students within the same lesson for action on her feedback. Where students do not act on the feedback within the next lesson, teacher can follow-up to complete the IFA cycle and ensure that the students act on the feedback. What is valued is also influential and will be considered next.

What is valued in the classroom

What is valued in the classroom drives many student actions and is another influence on students' uptake of feedback from the teacher-student dialogue in IFA. What is valued in the classroom by the teacher is subconsciously accepted by the students and they learn what they do most in the classroom (Nuthall, 2007). If what is valued in the classroom is the production of a technological outcome – students are likely to focus on finishing the outcome as quickly as possible. If what is valued is the aesthetics, students are likely to focus on aesthetics. If the students get special privileges on finishing the work, they are more likely to focus on the quickest and easiest path to finishing the work.

Jean understood the experiences that students had in the classroom shaped their opinions and future actions. During a group discussion, Jean heard students debating working independently versus working in groups and she was struck by the fact that students supported the viewpoints based on their experience in the Plastic unit where students could choose to work independently or in groups. When students were asked to work in groups in the Cardboard unit, all but two students expressed positive experiences of working in groups at the end of the unit. The evidence indicates that student experiences in the classroom have to be recognised by the teacher. Not all experiences are planned by the teacher and teachers can find it difficult to be aware of what the students are experiencing (Nuthall, 2007).

The teacher influences the focus and effort put in the learning by the students by valuing certain aspects of the technological practice. Hence, it is necessary for teachers to be clear about what their focus for the technology unit is. In this study, Sarah-Jane's focus was on making sure students understood the use of different components of the water filter and the students working together in groups. This focus was evident from the analysis of the dialogue in Sarah-Jane's classroom. Accordingly, students demonstrated more learning in these aspects. For Jean, her focus was ensuring that every student had some technological outcome and poster for the market day. Accordingly, all students worked on achieving these targets in Jean's class. Jean focused on creativity in the initial brief development phase and ensured that many student groups changed their design plan accordingly in the first week. However, after the first week, students who had not followed the feedback or students who felt any struggle with their design plans in the second week, focused on finishing their technological outcome as that was the focus in the second week. Hence, a consistent focus that values specific aspects of learning is likely to lead to students working to meet those expectations. The students' uptake of teacher's feedback is likely to be overtaken by these other expectations related to what is valued in the classroom.

Psychological reasons relating to students

Students may not work on the feedback due to many reasons - some pragmatic (tiredness, hunger, being upset etc.), some motivation related and some psychological reasons such as lack of persistence or risk aversion, peer pressure, status-quo bias, or reactance. The theory of student motivation is vast and no attempt is made at completeness of the review as student motivation was not a focus of this study. The most relevant range of possibilities that teachers can influence on are discussed here so that teachers can be on lookout for these reasons.

Persistence or resilience can be affected by the students' perception of how useful the feedback is and are given a chance to respond to the feedback (Wiliam, 2019). Students are engaged and motivated if they feel there is some benefit in what they are doing (Müller, 2008). Students are also engaged and likely to persist, if they have a goal for learning (Ivankova & Stick, 2006) or consider the learning process as one of personal challenge or opportunity for growth (Müller, 2008; Yang et al., 2017). Teachers need to link the learning goals clearly to students' interest. Students are more likely to feel engaged and persist if they have an authentic learning experience that they can link to their present and future lives (Ivankova & Stick, 2006).

Students could also be unwilling to take too much risk especially if they feel threatened about the consequences of their failure. One way for teachers to encourage more risk is to create a safe classroom environment where failure is considered as part of the learning process. In a study to increase resilience for mathematics, C. Lee and Johnston-Wilder

(2017) explained that a safe environment, challenging, relevant, and interesting problems to solve are likely to help participants to be more resilient. Persistence or resilience is also linked to having a growth mindset (Johnston-Wilder et al., 2013) - a belief that abilities are not fixed and can be developed over time. C. Lee and Johnston-Wilder (2017) advised teachers to teach about the growth mindset that is based on Dweck's work (Dweck, 1999).

A status-quo bias (Samuelson & Zeckhauser, 1988) is linked to a fear of failure and loss aversion. Students are unlikely to comply with changes to their design in the fear that by changing their design they are more likely to fail, in this case by not having a completed technological outcome. They may have been biased towards maintaining a status-quo and minimising their loss. Students might perceive that changing their design in line with teacher's feedback rather than continuing what they were doing could lead to loss of time or loss of resources that they cannot afford at that moment. One way to overcome this would be to provide additional support to the student to recognise the pros and cons of shifting from the status quo and encouraging them to learn from their reluctance. A second way to overcome this is to encourage students to learn from their failures.

Students could also avoid any changes due to peer pressure. Other students could influence a students' action by minimising the need to change due to other priorities in the classroom or alternate suggestions. A student given the suggestion could then choose to follow the other students and ignore the feedback by the teacher. Nuthall (2007) mentioned in his study the importance of peer opinions and suggestions and their influence in the student actions and learning in the classroom. Peer pressure can be influenced by the classroom culture that the teacher cultivates (Nuthall, 2007). The teacher can encourage a classroom culture where peers help each other and encourage each other to think deeply about their thinking, actions, and non-actions.

It is possible, although not likely, that students could be unwilling to make any changes based on reactance theory (Brehm & Brehm, 1981). According to reactance theory, individuals believe they have certain freedom and are likely to fight against perceived threats to their freedom. Reactance theory is one explanation to why patients do not follow doctor's advice (Fogarty, 1997). If students perceive any suggestion as a threat to their personal freedom, they are unlikely to make the change. Mühlberger and Jonas (2019) suggest some evidence-based methods to reduce the reactance. Some of these methods are discussing the reasons for the threat, reinforcing the freedom of the individual, or forewarning them about the threat (Mühlberger & Jonas, 2019).

In summary, there could be many psychological reasons for students to be unwilling to incorporate feedback. There is limited research in the field of TE over these factors specifically applied to students attempts in TE. In this study, some of these psychological effects could have prevented the uptake of the teacher feedback. Future studies can investigate these reasons in more detail as they lie beyond the scope of this study. However, creating a safe classroom environment where students can openly discuss their thoughts and feelings, teacher's follow-up with students on the feedback, building a culture where failure is considered as learning experience, providing authentic experiences, having clarity in learning goals are some ways to support students' uptake of teacher's feedback.

7.4 Chapter summary

In this chapter on discussion, I discussed the response of this research to the three research questions. The three research questions related to how teacher's beliefs impacted IFA in TE and how were students impacted by IFA. Besides the teacher and students, the discussion aimed to respond to model of IFA that are discussed in literature as well as explain why IFA is a complex process. While a detailed conclusion is presented in the next chapter, I briefly summarise some key points of this discussion.

IFA model in literature is often depicted in a cycle and I argue for the depiction to be a spiral. Additionally, I argued for addition of two extra stages - student action and teacher follow-up to ensure that the feedback cycle is complete. IFA is a complex process as teachers recognise and aim to progress the learning of multiple students across multiple objectives in a few minutes. Teacher's beliefs about importance of TE and importance of student voice will aid their IFA practice and their knowledge in TE will help them progress the student. The framework designed in this study, QFT-P can prove to be an important tool for IFA. However, using the QFT-P for inexperienced teachers can be an overwhelming undertaking due to the cognitive load on the teacher. Students do learn technology objectives and key competencies through dialogue. However, they may not always implement or think through teacher's feedback.

Chapter 8

Conclusion

> Application is as much an intrinsic part of genuine reflective inquiry as is alert observation or reasoning itself (Dewey, 2011, p. 214).

In this research, the response to all research question was through analysing teacher-student dialogue for finding insights on formative assessment in TE and the influence of the dialogues on student learning. As the formative assessment was conducted through use of QFT-P, the findings were focused on how the QFT-P was used as a formative assessment tool in the classroom. The discussion chapter further contextualised the findings of this study against the existing literature. This chapter aims to present the conclusion of the study.

Accordingly, this chapter is divided into responses to the three research questions followed by discussion of the implications of this research. Following the conclusions and implications, the original contribution made by this research is highlighted. Limitations are briefly discussed followed by a discussion on potential for future research.

8.1 Response to the research questions

What insights can be gained about Interactive Formative Assessment in Technology Education through an analysis of teacher-student dialogue?
Formative assessment in TE is mainly done through interactions and dialogues that is, it is mainly of the type IFA. In literature, IFA was shown to have three steps: elicitation, student response, and teacher feedback (or using the information) (B. Bell & Cowie, 2001; Ruiz-Primo & Furtak, 2006, 2007). This research proposes addition of two more steps to the IFA process - Student action (A) and Teacher follow-up (F) to ensure the completion of the IFA cycle - known in research to aid student learning (Rached & Grangeat, 2021; Ruiz-Primo & Furtak, 2007). In this research study, in many instances, students received teacher feedback. However, they did not always act on the feedback

- either by implementing it or by proposing an alternate understanding. Considering the time and effort in having dialogue with the students and providing feedback, an opportunity was lost for the students and teachers to gain insights into why the feedback was not pursued.

IFA is a complex process where the teacher is eliciting multiple pieces of information and is interpreting and acting on the collected information for multiple students simultaneously all the while managing the general dynamic nature of the classroom. It is not surprising then that the teacher has few opportunities to speak to a single student. Hence, the feedback given in those few opportunities, needs to be of high-quality and subsequently be utilised by the student. Follow-up by the teacher is essential for ensuring the implementation of the feedback. However, follow-up may be minimised without compromising student learning by teaching and modelling for students, self-regulation strategies. Self-regulation can have positive effect on student learning.

The IFA process is a spiral as the student learning is developing. While theoretically the learning along a spiral can be infinite or long, the learning spiral is often cut short in the classroom due to various constraints. Besides institutional constraints such as the school's requirements, policy documents, societal expectations, availability of resources, there are constraints within the classroom such as needs of other students, teacher's content knowledge, time, and student's ability and existing knowledge at that point of time. By understanding that IFA can be an upward spiral, teachers can make decisions on how to differentiate learning for learners and groups.

How do teachers' beliefs and knowledge impact Interactive Formative Assessment in Technology Education?

Teacher's beliefs and teacher's knowledge impact the teacher's practice in the classroom and hence, IFA. Teachers beliefs regarding the importance of student voice will impact whether they will have dialogue with the students. Teacher's beliefs regarding the importance of TE is likely to influence how much time they spend having dialogue in the classroom. For teachers to have clarity on the goals in TE, teachers may need to work on their content knowledge. However, it is likely that the teachers have implicit knowledge about technology as consumers. This implicit knowledge needs to be made explicit and transferred to the teacher's technology content knowledge.

QFT-P can act as an enhancer to IFA in the classroom for teachers of any experience or any belief. However, the beneficial effects of using the QFT-P depends on the teacher's beliefs and teacher's knowledge. Inexperienced teachers may find it difficult to change their practice due to cognitive load. Teachers should adopt any new practice slowly.

What influence does teacher-student dialogue for formative assessment have on student learning in Technology Education?
In this study, the teacher-student dialogue for formative assessment offered mixed results on the student learning. In some cases, the students improved their technological outcome and demonstrated learning in TE curriculum areas as well as teacher's priority objectives. In other cases, the students seemed to ignore the feedback they received in the dialogue or did not demonstrate learning through their outcome. For student learning to be demonstrated, there needs to be some record of their learning either in their dialogue or their reflection.

Students' uptake of teacher feedback is not straightforward and influenced by many factors. Teacher's feedback needs to be appropriate and teacher needs to be responsive during the dialogue where they provide the feedback. After feedback is provided, a follow-up by the teacher is needed - either initiated by the students or the teacher. In the follow-up dialogue, the student can ask for any clarification and the teacher can provide scaffolding for any further action. What is valued in the classroom will determine the students action and may prevail over the feedback. Where students worked on teacher's feedback, there was evidence that the feedback was well understood and subsequent action for the feedback was seen within the next class. Any further time delay implies that the student is unlikely to apply the feedback to their work.

Students may not deliberate over teacher feedback for various psychological reasons. Some of these reasons may be preference of status-quo and their existing thoughts and beliefs, peer pressure that is in opposition to the feedback, low persistence arising due to to a fixed-ability mindset or feeling the need to preserve personal freedom. One important way to combat many of the psychological factors would be to adopt a growth mindset in the classroom. Teachers can emphasise the students' ability to learn and grow and learn from mistakes. While following-up on the feedback, the teachers can discuss with the student about their reluctance to change due to status-quo bias or reactance and offer perspective on why the student may need to at least think of the feedback and reason for their beliefs about their actions.

8.2 Recommendations arising from the study

There are two main recommendations regarding using QFT-P and Professional development in TE.

8.2.1 Using QFT-P

There is positive evidence for the use of QFT-P as a formative assessment tool in TE. QFT-P aided teachers to have longer dialogue with students, aided teachers and students to learn about technology content, and have a positive impact on student learning. QFT-P did not increase the workload of the teachers within the classroom and was near zero cost for using it directly in the classroom. However, the QFT-P requires teachers to invest some time to become familiar with the questions. Some content knowledge is required for using the QFT-P and providing professional development to teachers for TE may be necessary.

The QFT-P was developed in this research study to be more user-friendly. The QFT-P's final form is in 41 cards. Teachers need to start by using only a few cards at a time. Inexperienced teachers may likely struggle with using QFT-P because of high-cognitive load due to the amount of new skills, practices, and knowledge they encounter. This implies that if the inexperienced teacher wants to use the QFT-P in the classroom, start with planning a few questions from 2-3 cards at the beginning and take as long as they need to use the questions from those cards and practice being responsive in the dialogue with the students before adding any more questions.

8.2.2 Professional development in Technology Education

The 2016 survey through NMSSA still showed a substantial population of primary teachers not being aware of TE curriculum or the IoP (Ministry of Education and NZCER, 2016). The NMSSA also showed that schools do not offer adequate support to the teachers to teach TE (ibid). This study offered evidence that novice teachers have a high cognitive load at the beginning of their career with regular classroom responsibilities. Without adequate support from the school, it is likely that novice teachers have limited experience in teaching TE. Besides lack of support from the school to teach TE, teachers are likely to want to explore different approaches such as PBL or teach through integrated STEM. Primary teachers will need to be made aware of the importance of TE and relative ease of TE integration in these approaches. A recent study showed that teachers participating in professional development in teaching integrated STEM was positively correlated with teacher's attitude towards STEM (Thibaut et al., 2018). By providing TE specific training, it is likely that teachers can assess their students more confidently due to increase in their self-efficacy (Hartell & Skogh, 2015). It can be inferred that professional development for teaching TE is necessary for primary teachers in NZ and is likely to positively influence teachers' attitude to teaching TE. However, I would like to add two characteristics for professional development for TE teachers based on the findings from this study.

A professional development or in-service training for TE will need to be dialogic and collaborative (R. T. Putnam & Borko, 2000; Reznitskaya & Wilkinson, 2015). Through dialogue, teachers can make their implicit knowledge about technology, explicit. They can reflect on how they interact with technology in their lives and connect aspects of their existing knowledge to technological concepts and the curriculum. This approach in a professional development is unique to TE as implicit knowledge about the subject is collected in a different domain - as a consumer - making it difficult to transfer to a classroom.

The second characteristic that will be particular to TE professional development for primary teachers relate to teacher beliefs. As shown in this study, teacher's positive beliefs about importance of TE are critical for teachers to be able to conduct formative assessment in TE. Other researchers (Buehl & Beck, 2015; Clark, 1988; Fives & Buehl, 2012; Skott, 2015) have pointed to the importance of teacher's beliefs in teacher's practice and have concluded on the importance of changing teacher's beliefs to sustainable change to teacher's practice (Guskey, 2002). In TE, the professional development needs to involve an exploration of the purpose, aims, and benefits of TE in primary classrooms.

Beliefs regarding the role of a teacher and student in the classroom have wide implications across all learning areas and drives the teacher's practice in the classroom. However, in TE, dialogue and dialogic approaches are critical to conduct formative assessment and to aid student learning in TE. The evidence from this study and the various literature reviewed offers ample reasons for the dialogic approach in TE. The teacher's beliefs about the importance of student voice in the classroom is a favourable condition for IFA in TE. Hence, if teachers need professional development to change their approach in classroom, it may involve long periods of exclusive focus, reflection, dialogue, and collaboration with other teachers and educators to make a long-term change in the teacher's approach.

To summarise, the two characteristics recommended for TE are a dialogue for making TE knowledge explicit and focus on teacher's belief about importance of TE and belief about the importance of student voice in the classroom. Ensuring the presence of these two characteristics in TE PD for in-service primary teachers is likely to engage the teachers in TE and set up a good foundation for them to conduct effective IFA in the TE classroom. Besides the two characteristics, it behoves facilitators and PD providers to follow other evidence-based practices from research on professional development. PD programmes need to be long-term and ongoing in order to provide adequate support to the teachers and be able to practice in the new ways (Bakkenes et al., 2010; Borko et al., 2008; Davies et al., 2017; Schneider & Plasman, 2011). Any PD must involve teachers reflecting on their practices (Davies et al., 2017). It is likely that follow-up sessions may be needed so that teachers can get adequate support to continue with the changed practices (Davies et al., 2017). So what are the implications for practice and policy? I'll outline some key implications in the next section.

8.3 Implications of this study

Based on the conclusions, there are some implications for teachers, teacher educators, and PD providers. There are further implications for policy makers and curriculum developers of TE.

For teachers, the evidence of their implicit knowledge about TE is good news. Even inexperienced teachers have content knowledge about TE. This knowledge needs to be made explicit and connect with the NZC documents like the Indicators of Progression. Using the QFT-P is an easy process in the classroom and can aid teachers in formative assessment in TE. However, IFA is a complex process and enacting IFA can cause a high cognitive load. Teachers should be patient with themselves as they enact IFA and progress students on their learning journey. While conducting IFA, teachers should follow-up on their feedback to the students and/or teach students self-regulation strategies to implement feedback. Clarity of learning goals for each part of the lesson is essential to ensure student is learning in TE.

For Principals, the implication from this study is about the importance of TE in the primary curriculum. Teachers can use TE as the space to use and develop key competencies from the NZC. The ease of integration of TE in multiple approaches in the primary classroom offers multiple benefits to primary students in the present as well as in preparation for high school. Principals need to provide time and resources for teachers to plan and teach TE.

Based on this research, professional development is needed in three areas:

- Teachers have implicit knowledge about technology education as consumers. This implicit knowledge needs to be made explicit. Teacher educators and PD providers need to train teachers using a dialogic methodology. PD related to improving content knowledge in TE may not need to be extensive and prolonged due to the presence of the implicit knowledge. This is good news for all TE educators.

- Teacher's beliefs can have substantial effect on conducting IFA. Changing beliefs is one of the toughest areas of professional development. The professional development will have to be ongoing and extended lasting more than one term.

- Teacher's are constrained to devote time to TE in primary schools. This implies that primary teachers need to have an honest dialogue with TE educators about the role of TE and strategies to integrate TE into their classroom no matter which approach the school and the teacher might follow.

Besides professional development, curriculum developers and policy makers need to continue to believe in TE and its potential to fulfil the aims of the NZC. This research shows teachers are drawn to using problem-solving approaches to help students of all kinds to fulfil their potential and become 21st century learners. Schools and teachers need knowledge and resources to strengthen TE's place in primary schools. Where IFA is concerned, it is to be remembered the complexity of the process and enough time needs to be allocated to teachers to improve their IFA practice.

8.4 Original contribution of this study

The original contribution of this study is to provide a concrete tool, QFT-P, for formative assessment in TE for students aged 5-12 years in NZ. QFT-P is made specially for TE and for primary students in NZ as it is aligned to the NZ curriculum because NZ has one of the most well-developed curriculum for TE in the world (de Vries et al., 2016). TE educators in other contexts are likely to find resonance with the questions in the QFT-P. The questions can be easily aligned and extended by TE experts for secondary students. The development process described in this study can guide TE educators on extending the QFT-P for their context.

Besides the QFT-P, this study proposed an extension to the model for IFA adding two steps to the existing models of IFA. The literature on IFA in any subject is quite limited. The proposed model of IFA can be applicable to any subject and be used by teacher educators. The findings about IFA in this study can be extended to formative assessment as well. In TE, formative assessment is mainly carried out through interaction. In other subjects, teachers may use other types of formative assessment practices. So, insights from this study about formative assessment are likely applicable to other subjects. Formative assessment is likely to be complex and will take time to implement in the classroom. Student uptake of teacher's feedback is applicable to all feedback given to students - whether written to oral. Need for follow-up after feedback is applicable across subjects for any type of formative assessment.

Additionally, in this study, it was recognised that teachers have implicit knowledge about TE that can be made explicit through a dialogic professional development. Teachers may easily recognise the elements of the TE curriculum from their personal experience as consumers of various technologies. The thesis also provided cognitive load as a possible reason for why inexperienced teachers might struggle to learn something new in the classroom with the implication that any new practice should be carefully introduced in the classroom and that a limited number of new experiences be undertaken at one time.

In this study, the analytical framework assumed that the QFT-P was a technology and analysed data based on whether the "technology" met the attributes for the stakeholder group. The analytical framework offers a robust method of analysis for other design-based research especially when there is a learning framework or tool being designed for use in the classroom. For purpose of using the analytical framework, researchers can begin the project by listing the attributes of the designed tool. This attribute list can be co-designed with teachers. Data can be collected and analysed against the list of attributes. Multiple cycles of research and improvement will ensure that the designed tool meet the requirements of the target audience. It is necessary that one of the attributes relate to the students' growth academically or students' well-being.

Alton-Lee had designed and used item-files for analysing student data. Nuthall used item-files in his study to understand how students learn a new concept. Few studies after Nuthall have used item-files to analyse student data possibly due to its rigorous and intensive nature. This study used a modified version of item-files - something that was well within the framework of a doctoral study. Instead of segmenting videos every few minutes, the focus was to look at the whole lesson. Another change was to not look at every concept taught in the classroom but to target selected ones. Definitely the modifications lead to some loss in the final analysis. However, the creation of item-files and subsequent analysis gives the full picture of the unit and can offer a good alternate to other methods of analysis of student data. There were some limitations that may have impacted on the full potential of the study being realised or for some of the conclusions to be positioned more tentatively.

8.5 Limitations

The main limitation has been missing data at both schools. I did not anticipate the students' missing worksheets on market research questions at Athena or students losing their products. Around half the class at Minerva did not consent to be part of the study. In every group, I could not use at least half of the data. My poor photography skills meant I did not take multiple photos or angles of the students technological outcome. While the missing data could have resulted a better insight on some of the findings in this study, triangulation of data from multiple sources and long period of involvement in the classroom helped mitigate the loss of data.

This study analysed the classroom data against the NZC. Curriculum documents are a function of the society in which they are designed. Students' learning could have been interpreted in other ways independent of the curriculum objectives. This research study did not focus on PCK and instead discussed findings based on teacher knowledge as a whole. Also, this study did not focus on the development of technology vocabulary in students which could be considered as a learning for students. Through undertaking this research study several areas for potential research were identified that were beyond the scope of the present study.

8.6 Future potential for research

There are many avenues of research that can be taken on the basis of this research's findings. Use of the QFT-P can be studied with other primary technology teachers. The QFT-P can be provided to experienced TE teachers for further insights on IFA by experienced TE teachers. Development of students' technology vocabulary by using the QFT-P is another potential avenue of research.

The QFT-P can be extended to secondary schools or a student version of QFT-P could be created for further study. Self-regulation, self and peer assessment is likely to influence how formative assessment looks in the TE classroom. Hence, a further avenue of study could evolve where students are taught self-regulation strategies and self and peer assessment. Further research is also needed in the area of complete and incomplete cycles of IFA and to examine the extended model in further classroom contexts.

8.7 Concluding statements

In line with my pragmatic lens, through this doctoral study, I hoped to be involved in a research that had a practical benefit and make a meaningful contribution to the field of Technology Education. Deweyan pragmatism embraces the many complexities of the context and work in authentic conditions. I worked with teachers and listened to them - after all, they were the experts on their students and their classroom context. I aimed for the findings of the research to be able to be used by other technology teachers. The QFT-P is the main contribution of this research and a concrete tool that teachers can use on the basis of this research.

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Appendix A - Technology Observation and Conversation Framework (TOCF)

(Fox-Turnbull, 2018)

Technology Observation and Conversation Framework

Behaviours ***Aspect***	**Resilience**	**Transference**	**Flexibility & Sophistication**	**Reflection**	**Socialisation**
Understanding of / exploring the technological (made) world MOST UNITS START WITH THIS ASPECT *NB: When *'technology' or technologies* is written replace it with the context of your students, i.e. what the children are designing and making.	**Look for:** using *technology* and having repeated goes at getting it right or improving use of an existing *technology*.* Total absorption while others are playing / working around them. Not letting others distract them. Hunting for the best device to do a particular job. **Ask:** How might you get better at using this? Who might help you with this? What might be a better thing to do this job? What can I do to help you with this? **Say:** Have another go. You are just not there yet. You can learn from getting things wrong.	**Look for:** transferring knowledge and skills in the use of one *technology* to another technology that might involve similar skills. Recognition of the similar skill sets. Deploying skills and knowledge used at home with a different technology at school. Recognising a range of 'made' things. **Ask:** Where else might you use this (action/ skills)? Have you done anything like this at home or with your family? Where have you seen this before? Have you used this before? Imagine what this might look like in 20 (50/100) years' time. What did you notice about the way that works? What questions would you like to ask the people who made this?	**Look for:** increasing understanding that *technology* is made for purpose. Different needs lead to different outcomes Students finding relevant information from unexpected sources increasing understanding that *technology* is made for purpose Understanding different needs lead to different outcomes **Ask:** Who might benefit from this *technology*? Why? How else might this *technology* be used? What are the benefits of this? What would you like to ask the person who made this to find out about how and why it works? Which do you think is the better/ best (comparing a range of similar items)? Why?	**Look for:** talk about why some things are made by people and some things are not. Questioning of how and why things work. Thinking about their thinking about technology. **Ask:** Tell me why this is *technology* is technology? How might this *technology* be improved? What works well with this *technology*? What is successful about this *technology?* What does not work well? What do you think about when you use this technology? How can thinking help you understand about this *technology*?	**Look for:** understanding that *technology* is usually made by groups of people working collaboratively. Technology is made for people. Understanding that many people influence *technology* design. Attempting to use technology by copying the actions of adults. **Ask:** Who makes stuff (technology)? Why? Do you think people worked together to design and make this *technology*? How do you know who might make this *technology*? D you think people work together to make this *technology*? How might they do this? Give me an example of something that is/ is not made by people.

Behaviours ***Aspect***	**Resilience**	**Transference**	**Flexibility & Sophistication**	**Reflection**	**Socialisation**
Evaluate current technologies (communicating ideas about the made-world)	**Look for:** willingness to have a go at articulating the physical and functional features and nature of existing *technologies.** Having several attempts at explaining the success or not, of *technologies* Having several attempts at getting something to work. **Ask :** What will make you better at using this ? **Say:** Try again to see if you can get a different result. Use different words such as: better than, different to, similar to, not as good as …., when talking about this *technology?*	**Look for:** use of evaluative language used to discuss *technologies* in one context transferred to another. Ability to imagine a better version of technology. Noticing similar features from one technology to another. **Ask:** How could you improve this for another group of people (state actual group)? Why was this *technology* made? Who else might want to make this? What changes would they make? Why? Have you seen this feature in something else? How have you used what we found out earlier about *X* in your plan?	**Look for:** increased awareness about the complexity of *technology* and that evaluations from different people will be very different. Understanding why what works for one person might not work for another. Imaging a more complex version or different version to better meet identified need. **Ask:** Why does this *technology* work so well? Who might this *technology* not work for? Why? Who might it work better for? What makes this *technology* safe to use? **Say:** Talk about successful design and ideas.	**Look for:** the ability to experiment with a *technology* and talk about how they might make it better. Children asking of questions as to why technology is the way it is. Questions about functional features. Questions about physical features. **Ask:** What makes this *X* a good one? How could you improve it? Why do you think this? How could this *technology* be made safer to use? Would your parents (Mum, Dad) use this *technology?* Would your parents (Mum, Dad) like this *technology?* Do you have the same or different ideas about this *technology* than your parents? Why?	**Look for:** recognition that designing and making *technology* is frequently undertaken in teams. Understanding that to evaluate *technology* a range of stakeholders -groups of people with a stake in the *technology* need to be considered. Comparing technology using language of more advanced peers or adults. **Ask:** How might this *technology* have been better if more people helped make it? How could other people help you to talk about how this *technology* works? What do you think Mum or Dad {or another important person in their lives) would think of this? Why do you say that? What features in this *technology* help keep us safe? How do you know this made by people?

Behaviours ***Aspect***	**Resilience**	**Transference**	**Flexibility & Sophistication**	**Reflection**	**Socialisation**
Identify technological problems or needs	**Look for:** an understanding that investigation is need to identify potential solutions. Understanding and practice that the design process may have to be repeated to obtain eventual success. **Ask:** How many ideas do you think you need? What would you change the second time if the first idea does not work?	**Look for:** the ability to transfer potential solutions from other situations to an identified need. Ability to recognise that a problem can be solved with a technological solution. **Ask:** What have you seen that is a similar problem/need to this? What do you know about recognising a *technology* problem from doing technology in school another time?	**Look for:** ability of offer a range of innovative solutions to a single problem. Ability to recognise that a technology solution is needed. Imaging a more complex version or different version to meet a different need. Recognising that a solution in one area might be modified to assist in another. **Ask:** Rank the ideas you have to this problem from best to worst? Tell me why they are in this order? What do you think might be the best solution to this problem? Why	**Look for:** Recognition of what circumstances led to a particular technological need. The ability to recognise a range of possible solutions and that some solutions are better than others Ability to justify the above. Recognising opportunities for developing technologies. **Ask:** Which is the best solution to this need? Why do you think this? What might be a better idea? Within this situation or scenario what is the technological need or what needs to be developed? Why?	**Look for:** the understanding that conversation and working cooperatively can assist the process of problem/ solution identification. Understanding that working together can mean doing different tasks on the same project. Imitating adults in the articulation of a technological problem and /or solution. Listening to others for ideas. **Ask:** How can working together help you decide the best solution to the problem? Who might help you think about doing this better? How might you help others to recognise an opportunity or identify the need?

Behaviours ***Aspect***	**Resilience**	**Transference**	**Flexibility & Sophistication**	**Reflection**	**Socialisation**
Design & make technological outcomes to meet needs including evaluating their design ideas and outcomes (contributing to the made-world through making and construction in a range of areas)	**Look for:** ability to continue working on a *technology drawing/ model/ outcome* to improve quality. Total absorption while others are playing / working around them. Not letting others distract them. Repeatedly giving things a go after initially failing. **Ask:** If your first idea does not work what will you do? What other detail can you put in your *drawing/ model*? How might you improve the quality of your *technology outcome*? **Say:** Try again to do this, but in a safer way. Like this (demonstrate skill)	**Look for:** skills learned in skills based lessons such as drawing, gluing, etc. used when making the actual *drawing/ model/ outcome.* Transferring identified attributes from *design* to the *technology outcomes*. Use of safe practices Use of research/investigation findings evident in planning/ drawing. **Ask:** What have you/we already learned that might help you with your *drawing/ model/ outcome?* Why/ How will this be useful? How did you determine the attributes? Who taught you to do that? How did you know that? Can you use (a feature) from something else? How can we do this safely? How have you used in your planning what we learned about?	**Look for:** detail in designs, ability to draw in 3D and annotate design ideas. Use modelling to inform technology practice and improve *technology outcomes*. Understand how modelling helps improve *technology outcomes.* Ensure design reflect required or desired attributes. Students drawing on relevant information from unexpected sources. **Ask:** Improve your design so that another person could make your *technology outcome.* Why and How does making a model improve you *technology outcomes?* What attribute/ feature is the most important why? What is the best bit of your design? What is your favourite part of the design/outcome?	**Look for:** ability to self and peer evaluate outcomes against established attributes or characteristics. Ability to recognise and justify changes for the next iteration of the design. **Ask:** What are the best features of this *drawing/ model/ outcome?* Why do you think this? If you/ they were to redo this or make improvements what changes should you/ they make? Why? Can you make your plan? What help might you need?	**Look for:** ability to work collaboratively with others. Ability to engage in intercognitive conversations, let own ideas go if necessary and move to new thinking with others. Embrace knowledge and skills brought to the group by others. Listening to others for ideas. **Ask:** How does working with other people help you? What ideas did you change after talking to *X/group*? What knowledge and skills did you know that the others didn't know and that helped your group? How can other people help you make your design?

Behaviours ***Aspect***	**Resilience**	**Transference**	**Flexibility & Sophistication**	**Reflection**	**Socialisation**
Understand key concepts of technology & deploy in their practice	**Look for:** ability to continue working on problem solving or developing a solution repeatedly after failure. Ability to name alternative suitable materials used. **Ask:** How can you make this better? What changes would you make next time? Who will benefit most from this design? Can you design it so others will benefit?	**Look for:** key concepts (these will differ according to curricula) learned in one unit transferred to another. Tasks that are identified in real *technology practice* transferred to students' technology practice Increasing complex drawing and modelling skills in subsequent units or projects **Ask:** What groups of people may not like this *technological outcome?* What are the main tasks for a technologist (a person who designs stuff)? What have we already learned that will help us with this design?	**Look for:** increased vocabulary sue when describing technology outcomes. Increasingly complex technologies recognised as technology. Increased complexity when considering factors that influence technology practice (theirs and others). **Ask:** What would a 'bad' *technology* look/ sound/ smell/ taste/ feel?	**Look for**: describe the *technological outcome* they are making Identify why they are making a *technological outcome.* Use of attributes to evaluate design ideas Discuss what is and is not technology and why Identify who might use a *technology* and why Comparing of their outcomes with pre-determined attributes. Ability to undertake self and peer assessment against identified attributes. **Ask:** What groups of people may not like this *technological outcome?* What groups of people will like this *technological outcome* best? Next time you made this what changes would you make? Why?	**Look for**: understanding the social and collaborative nature of technology and technology practice. Understanding the technology influences people and people influence technological development **Ask:** What groups of people may not like this *technological outcome?* What groups of people will like this *technological outcome* best?

*NB Where the words are italicised they may be replaced with the specific context the children are working in.

Appendix B - Question guide for the interview

Research title: Exploring the effects of classroom interactions on teachers and students' learning in technology education in primary classroom

Background information

1. Name:
2. Name of the school:
3. I have been teaching for ___________ number of years
4. Currently I teach Year _____
5. These are the areas of technology I have taught (Tick all applicable)

___ Digital technologies ____ Resistant materials _____ Food

_____ Textiles ___ Biotech ____ DVC _____ Electronics

6. Number of weeks of formal professional development in technology _________
7. For how many weeks in the last school year did you teach technology? __________
8. On a scale of 1 to 10, 1 being the lowest and 10 being the highest, please rate how confident you are of teaching technology ______

Semi-structured interview questions for the teacher

Interview 1: Pre-interview: (Understanding the teacher, classroom, students)

- Tell me something about your beliefs about teaching.
    - *Prompts: Teaching philosophy, role of teacher, role of students, feelings about assessments (assessment criteria, questioning, feedback, self and peer assessment)*
- Please draw a visual of technology education. Make any kind of visual that you are comfortable with (like concept/mind map, tree diagram, etc). If not comfortable with drawing, write key words on the paper that you relate to technology education. Can you explain what you have drawn/ written? Can you now fit in these words on your map?
    - *Prompts: Definition of technology, importance of technology education, important aspects while teaching technology, sources you use for planning lessons, assessments in technology, critical incidents (happy or challenging memories), integrating strands from the 3 technology areas, struggles while teaching*
- Describe a model lesson that you have experienced (taught/ seen/ read) in technology? Why do you consider that a model lesson?
    - *Prompts: Teacher actions, student actions, classroom interactions, assessments?*
- (From the background questionnaire) How do you rate your confidence for teaching technology ____? Why?
- What do you notice about students in technology lessons?
- What would you say or do in a situation where…
    - Student is unable to think of any design ideas or is stuck in any stage of planning
    - Student makes a model that does not align with brief
    - Student makes a mock-up that does not match his/her drawing
    - Student designs an outcome that does not agree with the client feedback
    - Student's final outcome is a failure

Introduction interview (Special emphasis on the temporal nature of TOCF – anyone can design it, flexible nature and how it can be changed as per needs)

- First thoughts/ impressions about TOCF.
- What do you notice?
- What do you already recognise?
- What is unfamiliar?

- What do you need to change in existing structures to use it? Do you think it is worth it?
- What strikes you as helpful about the framework?
- What behaviours do you agree with?
- Inclusion of which behaviour surprises you?
- Which of these questions do you already ask in the technology classroom?

Through the unit

- How was the lesson today?
- How did you use TOCF?
- Any specific insights you would like to mention
- What did you notice about the students working in technology today?

Interview after Unit 1

- ### Teacher experiences with the framework (RQ2)
    - How confident are you about teaching technology? (On a Likert scale) Why? (relate to previous rating and ask for reasons for change)
    - Can you tell me your thoughts on the TOCF?
    - Can you mention some critical incidents from the unit? (Prompt from own observations in case the teacher cannot recall)
- ### Stimulated recall (RQ1)
    - Choose 3-5 portfolios/ artefacts of the students' final work and talk about them.
        - Why did you choose those?
        - What aspects of this work strikes you as important?
        - What understandings does the student show?

Interview after Unit-2

- ### Teacher experiences with the framework (RQ2)
    - How confident are you about teaching technology? (On a Likert scale) Why? (relate to previous rating and ask for reasons for change)
    - Can you tell me your thoughts on the TOCF? Has this changed from the last unit? How?
    - How do you think TOCF influenced your practice?
    - Can you mention some critical incidents from the unit? (Prompt from own observations in case the teacher cannot recall)
    - What would your advice be to other teachers and the researchers about the TOCF?
- ### Stimulated recall (RQ1)
    - Choose 3-5 portfolios/ artefacts of the students' final work and talk about them.
        - Why did you choose those?
        - What aspects of this work strikes you as important?
        - What understandings does the student show?
    - Are you satisfied with how your students' are working in technology? Why? Why not?

Appendix C - Ethics approval

Te Kura Toi Tangata
Faculty of Education
The University of Waikato
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FEDU Ethics Committee

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THE UNIVERSITY OF
WAIKATO
Te Whare Wānanga o Waikato

8/11/2018

Dear Swathi Rangarajan

FEDU Ethics Application Approved FEDU082/18

I am pleased to advise you that your ethics application for the project entitled "Exploring the effects of classroom interactions on teachers and students' learning in technology in primary classroom" was approved by Te Kura Toi Tangata Faculty of Education Ethics Committee on November 8th, 2018.

Please be aware that the Te Kura Toi Tangata FEDU Ethics Committee must be advised (by memo) of any changes to the details recorded in your ethics application. Please send any such advice to fedu.ethics@waikato.ac.nz. You will receive a memo of approval once the change(s) has been considered.

We wish you all the best with your research.

Kind regards

Co-chair
Te Kura Toi Tangata Faculty of Education Ethics Committee

Appendix D - Questioning Framework for Technology - Primary (QFT-P)

Reflection

Researching similar technologies

Level 1

- What are the main tasks for a technologist (a person who designs stuff)?
- What do you think about when you use this technology?

Level 2

- What knowledge have you learnt by studying this product?
- What (part/ feature) in this technology was a new learning for you?
- What did you notice about the way that works?

Transferance

Researching similar technologies

Level 1

- Have you seen this feature in something else?

Level 2

- What do you know about recognising a technology problem from doing technology in school another time?
- What are some things about *this technology* that you can use for your design?
- What have we already learned that will help us with this design?

Socialisation

Researching similar technologies

Level 1

- Who makes stuff (technology)? Why do you think that?

Level 2

- What groups of people will like this technological outcome best? Who will not like it?
- What do you think Mum or Dad {or another important person in their lives) would think of this? Would they use it? Why do you say that?
- What would you like to ask the person who made this to find out about how and why it works?
- How is X feature in this product showing that it is designed for Y person? What makes you say that?

Resilience

Researching similar technologies

Level 1

- Do you think it was an easy job to design this? Why do you think that?

Level 2

- How long do you think this technology took to design and make?

Sophistication and Flexibility

Researching similar technologies

Level 1

- What are the benefits of *this feature/ this design*?
- Of the following which are technology: tree, computers, hammer, birds, bird nest, pen, book, bread, shirt?
- What makes this technology safe to use?
- Who do you think this technology is made for?

Level 2

- What is successful about *this technology*? What is not good about it?
- How do you think *this technology* was developed through the time?
- How do you think *this technology* changed the way we live?
- Can you name some technology that has helped (or not helped) the society?
- Tell me why *this technology* is technology
- How does technology having X feature help it do its job?
- What would a 'bad' technology look/ sound/ smell/ taste/ feel?
- How else might this technology be used?
- What makes this product a good design?
- What features in this technology make it safe to use?

Reflection

Level 1
- Can you make your plan? What help might you need?
- What is your next step?

Level 2
- Why do you need these features?
- How does planning help you make a better product?

Planning and criteria

Transferance

Upto Level 2

- What have you seen that is a similar problem/need to this?
- How have you used in your planning what we learned about?

Planning and criteria

Socialisation

Level 1
- How might you help others to recognise an opportunity or identify the need?

Level 2
- Who can help you do this (step) better?
- How will you convince your stakeholder that this will solve their problem?
- How will you plan this project as a group?

Planning and criteria

Resilience

Level 1
- What else could you add to your list of features that will make your end product better?

Level 2
- What will you do if you do to get more ideas?
- What will you do if you get delayed?
- (If the student made any mistake during the making) How is this going to change your plan now?

Planning and criteria

Sophistication and Flexibility

Level 1
- Within this situation or scenario what is the technological need or what needs to be developed? Why?
- What do you need in terms of materials next?

Level 2
- What attribute/ feature is the most important? Why?
- How have you designed your product for the specific need of your target audience?
- What are the steps to make your design?
- What materials will you require for each stage?

Planning and criteria

Reflection

Making and reflection

Level 1
- What are you making? Who are you making it for?

Level 2
- What are the best features of this drawing/ outcome? Why do you think this?
- What was difficult about making this final product?
- What did you find easy while making this product?
- What can you do better next time?
- (At the end) What are the steps to make a good quality outcome?

Transferance

Making and reflection

Level 2
- What skill did you learn in making this product?
- Have you done anything like this at home or with your family?
- Can you use (a feature) from something else?
- How have you used what we found out earlier about X in your plan?

Socialisation

Making and reflection

Level 1
- Who taught you to do that?
- How does working with other people help you?

Level 2
- How can other people help you make your design?
- What knowledge and skills did you know that the others didn't know and that helped your group?
- What ideas did you change after talking to X/group?

Resilience

Making and reflection

Level 1
- What can I do to help you with this?
- If your first idea does not work what will you do?
- How many ideas do you think you need?

Level 2
- What would you change the second time if the first idea does not work?
- What might be a better thing to do this job?
- In making this design, what mistakes did you make? How did making those mistakes help you?
- (If the mistake did not help) How did making the mistake change your brief or the attributes of your final outcome?

Sophistication and Flexibility

Making and reflection

Level 1
- Show me what you have drawn (Look for multiple plans)
- How does the final product solve the problem?
- How is the final product in line with your earlier drawing?
- How is the final product NOT in line with your earlier drawing? Why did you make those changes?
- How can we make this safely?

Level 2
- Rank the ideas you have to this problem - from best to worst? Tell me why they are in this order?
- Which of these ideas do you think meets all the requirements?
- If you made a checklist for all things the product should have, how many does this final product meet?

Reflection

Drawing and material selection

Level 1
- Do you like *this material*? Why?
- Is *this material* technology?

Level 2
- How does this model help you in your design and making process?
- In what ways does this model NOT help you to arrive at your final product?
- What are some disadvantages of *this material*?
- What could be some alternate material you could use if you had it? Why?

Transferance

Drawing and material selection

Level 1
- When you last made a model, how did it help you?
- In what other product have you seen this material used?
- Have you made something from this material before?

Level 2
- What have we already learned that might help you with your drawing/ model?
- Have you ever done/ seen this type of drawing before? Where have you seen/ done it?
- From your previous use of this material, what can you tell about how easy it is to make things out of this?

Socialisation

Drawing and material selection

Level 1
- What do your parents think of this material?

Level 2
- Does modelling help you explain your ideas to others? In what ways does it help? In what ways does it not help?
- How did drawing/ mock-up help you as a group?
- In what ways is this material good for our society?
- In what ways is this material NOT good for our society?

Resilience

Drawing and material selection

Level 2
- What can make your model quality better?
- If your material doesn't work, what other material can you use?
- If your material runs out, what else can you use?

Sophistication and Flexibility

Drawing and material selection

Level 1
- What is *this drawing/ this mock-up* called? Does it help you – how?
- Is this a final product? Can you go and sell it? Why or why not?

- What do you think *this material* is made of? Where does it come from?
- How does this material help this product work?

Level 2
- How can you use X type of functional modeling to test your design?
- Which of the final attributes of your product can this prototype help you test?
- Why and how does making a model improve your *technology outcomes*?
- What other detail can you put in your drawing/ model?

- What do you think are some of the properties of this material?
- Why do you think *this technology* can be made from this material?
- How will you cut and join this material for making your design?

Reflection

Level 3

- If you were to redo this or make improvements what changes should you make? Why?
- What kind of knowledge, information or skills do you think making *this product* requires?
- How might this technology be improved?
- What makes this design (from a range of similar products) a good one?

Level 4

- Think of your life without X, how would your life change?
- If everyone could have X technology, how would your life change?
- Does something about this design confuse you? What knowledge do you currently lack to truly understand this?
- If it was your job to design this technology, what kind of practices would you implement in your manufacturing line to get a good outcome?

Researching similar technologies

Sophistication and Flexibility

Level 3

- Give an example of a technology which has changed over time and its influence on society/ environment through time.
- If you had to worry about specific *environmental concern* (example: decomposable packaging, vegan) how would the product design change?
- If you had to consider the non availability of specific resource, how would the product change? How would the testing process change?
- Which do you think is the better/ best (comparing a range of similar items)? Why?
- Do you think this has a good design? What makes you say that?
- Why do you think this technology changed? Which specific feature has changed the most?

Level 4

- Give an example of a technology that has changed human physical limitations - either positively or negatively
- In this product design, according to you, what has been very creative?
- If X was the user, Y was the purpose, what kind of features and functions should the technology have?

Researching similar technologies

Transferance

Level 3

- Have you used this before? Imagine what this might look like in 20 (50/100) years' time. Why would it change or not change?
- Where else might you use this (action/ skills)?

Level 4

- In this product design, what has been taken from other subjects or areas like science or maths?

Researching similar technologies

Resilience

Level 3

- What information have you got from *this technology* to help with your design?
- Do you know an example of a technology that had to wait for society/other technologies to develop?
- What margin of error or tolerances are needed for (specific part of) this technology?

Level 4

- There are two ways of making a critical technology product. One requires an extra month to manufacture it and the other requires extra material to manufacture. Either way the manufacturing cost is the same. Which way would you choose and why?

Researching similar technologies

Reflection

Level 3

- Why do you need these features?
- How did you determine the attributes?
- What are the key dates in your project?
- What stage are you in now? What have you done till now? What is the next deadline?

Level 4

- (If they are falling behind) How is your planning going to change? Show me the updated planning tool.
- How does this brief development process help with the outcome development? What can you do to make this process more effective?

Planning and criteria

Transferance

Level 3

- What scientific concept can help you with your design/ testing process?
- What have you learnt when preparing this brief that you can use next time?
- Have you planned a project before? What did you learn from that experience?
- What have you learnt from this planning process that you can use next time?

Level 4

- What kind of tool that you have used/ seen that can help you keep track of all attributes through your design process?
- From your last technology practice, what have you ensured in the planning stage to do differently this time?

Planning and criteria

Socialisation

Planning and criteria

Level 3

- Who might help you think about doing this better?
- Did you face any issues while planning in the group? Give some examples.

Level 4

- What features are the most important for your stakeholder?
- How would you split the tasks among the group to make best use of everyone's skills?

Transferance

Making and reflection

Level 3

- What skills and knowledge did you apply from other areas of learning? Maths, Science, previous technology units?
- What new skills and knowledge have you learnt that you can use in other areas of your life and school?

Level 4

- What did you learn from the stakeholder feedback? How can you apply that learning next time?

Resilience

Planning and criteria

Level 3

- What will you change the next time you attempt this?
- What problems are you likely to face in this process? What plan do you have to help with those problems?

Level 4

- How will you keep yourself motivated when you have to revise the brief again and again?
- How will you handle the situation if your stakeholder(s) do/does not like your design?
- How often do you think you will need to change your plan? How often do you plan to review it?

Sophistication and Flexibility

Planning and criteria

Level 3

- To fulfil the need, how will you test your outcome?
- To incorporate your features, what do you have to make sure of in the design process?
- Of the features you have designed, which are the most important? How will you make sure that your final product will definitely have them?
- How is your design's physical features going to meet the need? How is its function going to meet the need?
- What will happen if you don't get this material at this stage?

Level 4

- Mention how you will test your outcome to prove that it is "fit-for-purpose"
- What is your conceptual statement?
- Show me your planning tool. (question if each stage is not marked clearly, resources planned for?)

Reflection

Making and reflection

<u>Level 3</u>

- Next time you made this what changes would you make? Why?
- What are the best features of this drawing/ model/ outcome? Why do you think this?
- What groups of people will not like/ be unable to use this outcome?

<u>Level 4</u>

- How has your thinking about technology changed while making this outcome?
- How have you changed your understanding of the technological process in making this outcome?

Socialisation

Making and reflection

<u>Level 3</u>

- How did working in a group help you make a better outcome? How did it not help you?
- What do you think was your contribution to the group in making the outcome? What do you think others contributed?
- How could you improve this for another group of people (state actual group)?
- How might this technology have been better if more people (in this class) helped you make it?

<u>Level 4</u>

- Identify a skill you are having trouble with. Who might you approach for help to improve this skill?

Sophistication and Flexibility

Making and reflection

<u>Level 3</u>

- Why did you choose to make X and not Y plan?
- Why is this component necessary in your design?
- Does this final product meet the initial brief? Defend.
- How could you make your outcome safer to use?

<u>Level 4</u>

- What other testing could you do to meet the requirement?

Sophistication and Flexibility

Drawing and material selection

<u>Level 3</u>

- What other detail can you put in your drawing/ model?
- Do you think modelling was enough? What more could you do to ensure a successful final product?
- What did the prototype tell you more than the modelling process did?

- What are the properties of this material? How do these specific properties help this product function and look?
- What specific properties of this material can be tested in a lab? What properties can be tested in other ways?

Sophistication and Flexibility

Drawing and material selection

<u>Level 4</u>

- What kind of modelling is the most suitable for your design? Why?
- What did you find out through the modeling and prototyping process? What did you change as a result in your final product?
- How did *this modeling technique* help you design the final product? In what ways did it not help you?

- How do you think this material can be manufactured/ manipulated for the end product?
- How do you think the process of manufacturing/ manipulating helped to make the end product?
- What are the technical specifications of the material for this technology? How can you indicate that so that others can read it?
- What kind of testing on the material are you going to do?

Resilience

Making and reflection

Level 3
- How can you make this better?
- (If the design fails) What or where has this design failed? What can you do better to succeed?

Level 4
- How might you improve the quality of your *technological outcome*?
- What features would you redesign to make the outcome more successful?

Reflection

Drawing and material selection

Level 3
- How can you become better at this modeling method?
- How do you join this material to other materials? What are your options?

Level 4
- What happens after you make a prototype? What could cause changes to the final product after the prototype is designed?
- If you had to mass produce this design, what would you change?
- Can you list 2-3 other alternative materials for your design. How will each of these materials change the attributes/ functioning?

Transferance

Drawing and material selection

Level 3
- What have you already learned that might help you with your *drawing/ model/ outcome*?
- Have you seen a model/ prototype of a building, bridge or any other structure/ product? What did that model tell you?
- What did you learn from the last time you used this material to make something?

Socialisation

Drawing and material selection

Level 3
- What type of modeling would appeal to your stakeholder?
- Who will not like this material? What other material can you use to work with these group of people?

Level 4
- If a technologist saw your prototype, what do you think they will do as next step?
- What elements of a detailed technical drawing can communicate your design to a complete stranger?
- Why do you need to write the complete technical specification of the material? What more can you do to make it effective for complete strangers to read it?

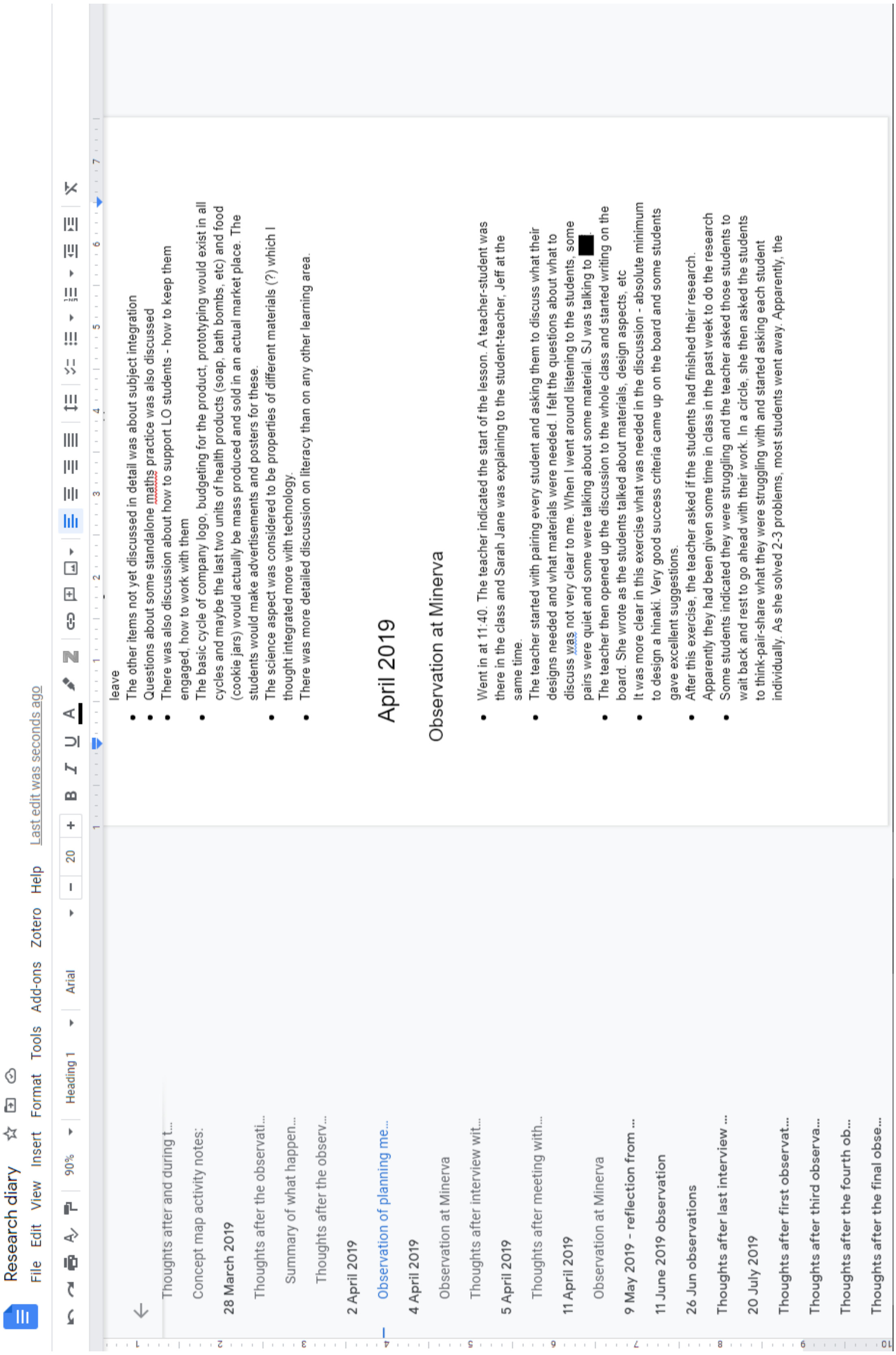
Resilience

Drawing and material selection

Level 3
- Do you find this modelling method difficult? What about it is difficult?
- How do you feel about working with this material? What can help you get a better quality output?

Level 4
- How many times have you had to revise your design from the earliest model to the final? Why did that help or not help?

Appendix F - Example of researcher notes



leave

- The other items not yet discussed in detail was about subject integration
- Questions about some standalone maths practice was also discussed
- There was also discussion about how to support LO students - how to keep them engaged, how to work with them
- The basic cycle of company logo, budgeting for the product, prototyping would exist in all cycles and maybe the last two units of health products (soap, bath bombs, etc) and food (cookie jars) would actually be mass produced and sold in an actual market place. The students would make advertisements and posters for these.
- The science aspect was considered to be properties of different materials (?) which I thought integrated more with technology.
- There was more detailed discussion on literacy than on any other learning area.

April 2019

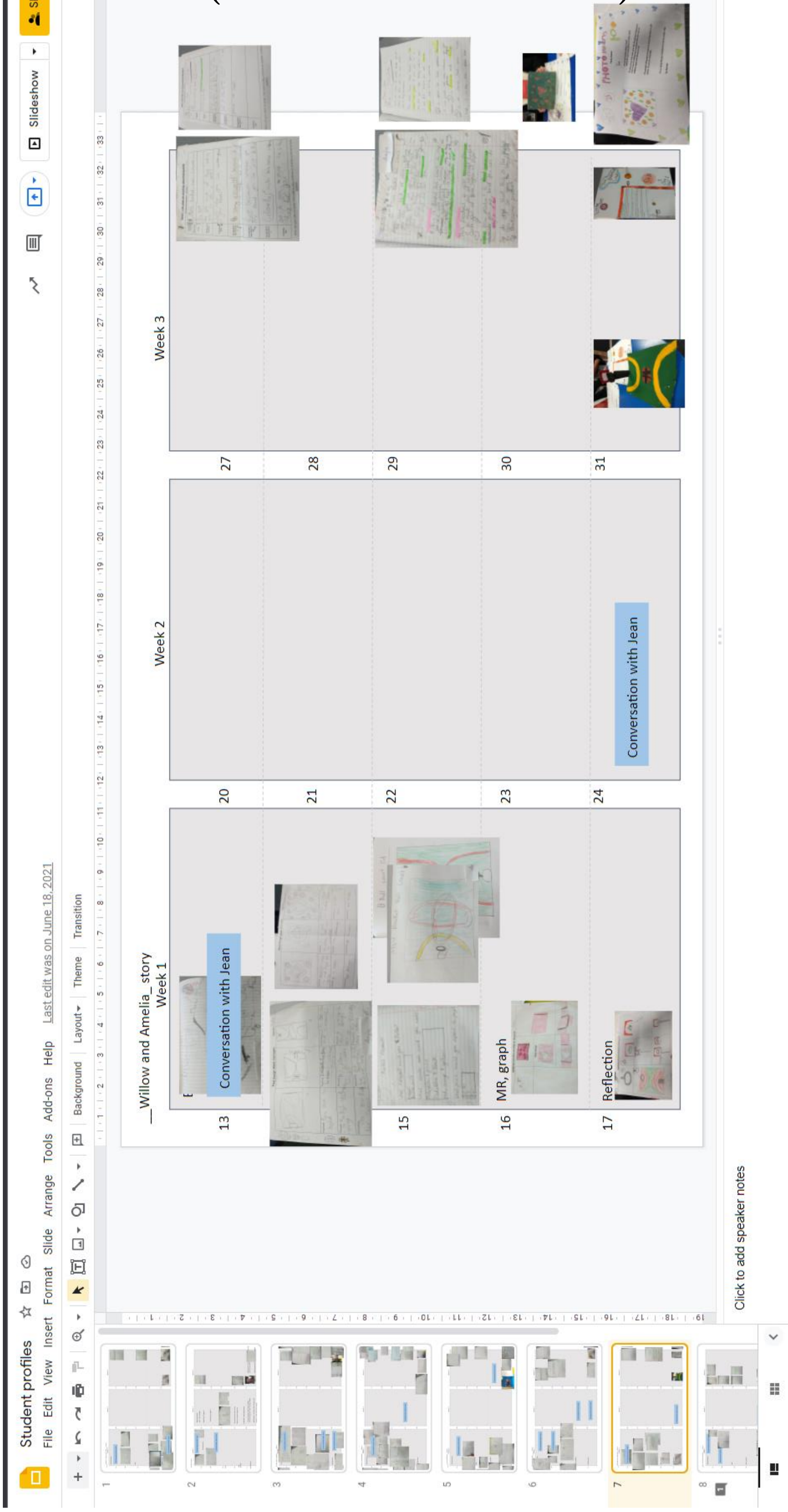
Observation at Minerva

- Went in at 11:40. The teacher indicated the start of the lesson. A teacher-student was there in the class and Sarah Jane was explaining to the student-teacher, Jeff at the same time.
- The teacher started with pairing every student and asking them to discuss what their designs needed and what materials were needed. I felt the questions about what to discuss was not very clear to me. When I went around listening to the students, some pairs were quiet and some were talking about some material. SJ was talking to [redacted].
- The teacher then opened up the discussion to the whole class and started writing on the board. She wrote as the students talked about materials, design aspects, etc
- It was more clear in this exercise what was needed in the discussion - absolute minimum to design a hinaki. Very good success criteria came up on the board and some students gave excellent suggestions.
- After this exercise, the teacher asked if the students had finished their research. Apparently they had been given some time in class in the past week to do the research
- Some students indicated they were struggling and the teacher asked those students to wait back and rest to go ahead with their work. In a circle, she then asked the students to think-pair-share what they were struggling with and started asking each student individually. As she solved 2-3 problems, most students went away. Apparently, the

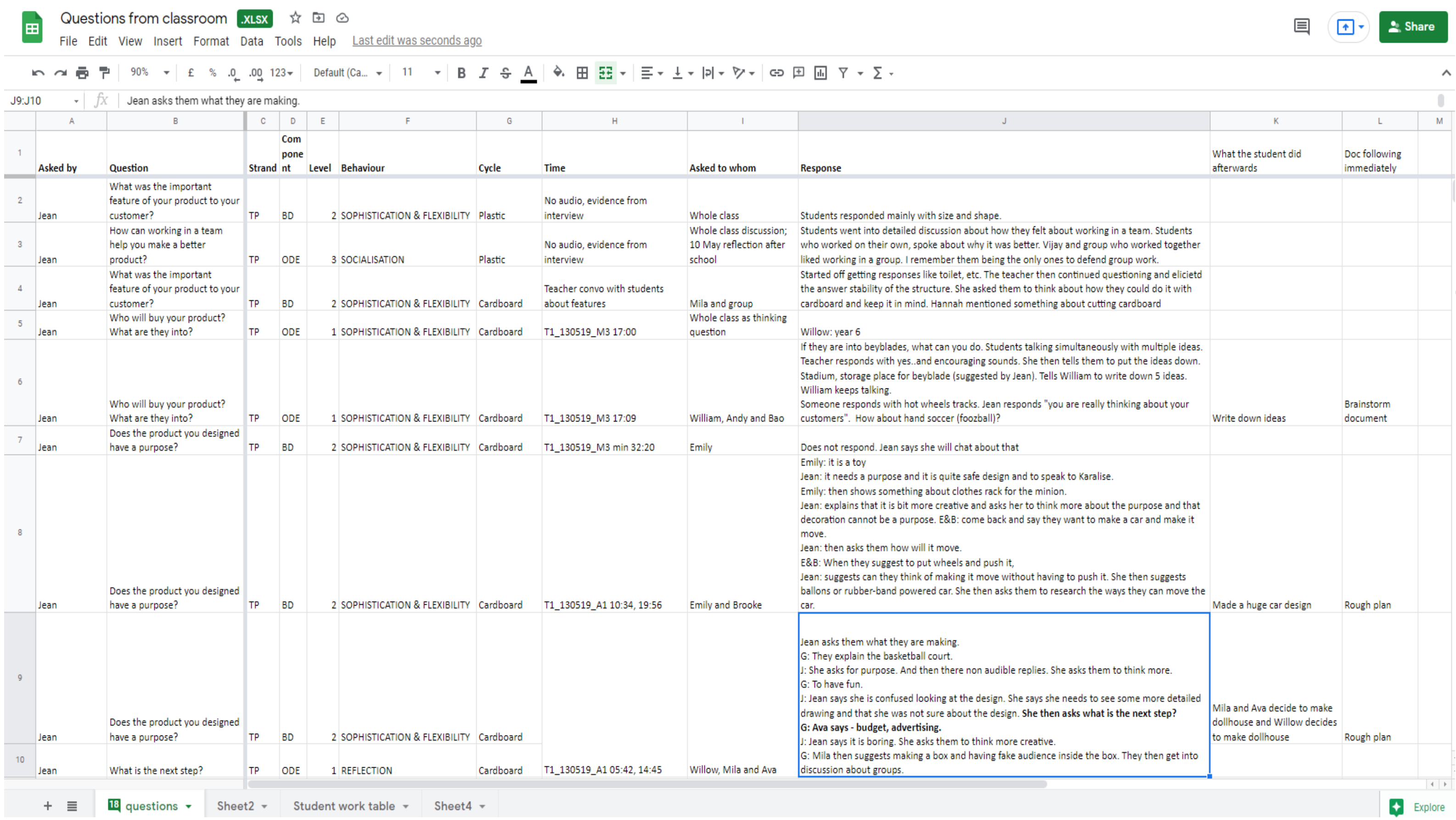
Appendix G - Example of timetable at Athena

Date		Monday 20-May-19	Tuesday 21-May-19	Wednesday 22-May-19	Thursday 23-May-19	Friday 24-May-19
9:00-9:15		Maths fitness and weekend talk	Roll and maths fitness	Roll and maths fitness	Roll call, maths fitness	Roll call, maths fitness, teacher talking about timetable
9:15-9:50	M1	Inquiry. Teacher talking to some students	Teacher teaching maths. Students working on projects	Teacher with maths group; rest working on worksheet	Group reading. Students working on maths/ project	Inquiry, teacher walking around talking to them
9:50-10:00		Brain break	Brain break	some students working on project	Brain break	
10:00-10:20	M1A	Fitness		Fitness	Fitness/ some students on project	
10:20-11:00	M2	Building. Teacher talking to some students	Milk, Kapa Haka	Library	Project work	Brain break, game, milk
11:00-11:30		Morning tea	Morning tea	Morning tea	Morning tea	Morning tea
11:30-12:00	M3		Reading groups. Students working on project	Silent reading		
12:00-12:20	M3A	Inquiry. Teacher working with literacy group		Teacher working with group. Rest on project		
12:20-12:45	M4	Fitness	Teacher working with specific students.	Fitness	Silent reading. Teacher working with reading group. Students on project work	R13 for reflection
12:45-13:45		Lunch	Lunch	Lunch	Lunch	Lunch
13:45-14:45	A1	Maori lesson, Inquiry, teacher reading group		Video. Reading. Inquiry/ teacher walking and talking to students	Reading by teacher students. Last 15 minutes, teacher walking around and spoke to students	Reading. Inquiry/ seesaw/ choosing time
14:45-15:00	A1A	Packup and teacher spoke about Mahi-tahi sheet	Reading by teacher. Reflection conversation using framework	Pack up	Pack up	Pack up
Remarks	This week the teacher worked with reading/ maths groups separately through the week					

Appendix H - Example of Google slides prepared for each student (modified item-files)



Appendix I - Sample of document with summary of audios from dialogue



Asked by	Question	Strand	Component	Level	Behaviour	Cycle	Time	Asked to whom	Response	What the student did afterwards	Doc following immediately
Jean	What was the important feature of your product to your customer?	TP	BD	2	SOPHISTICATION & FLEXIBILITY	Plastic	No audio, evidence from interview	Whole class	Students responded mainly with size and shape.		
Jean	How can working in a team help you make a better product?	TP	ODE	3	SOCIALISATION	Plastic	No audio, evidence from interview	Whole class discussion; 10 May reflection after school	Students went into detailed discussion about how they felt about working in a team. Students who worked on their own, spoke about why it was better. Vijay and group who worked together liked working in a group. I remember them being the only ones to defend group work.		
Jean	What was the important feature of your product to your customer?	TP	BD	2	SOPHISTICATION & FLEXIBILITY	Cardboard	Teacher convo with students about features	Mila and group	Started off getting responses like toilet, etc. The teacher then continued questioning and elicietd the answer stability of the structure. She asked them to think about how they could do it with cardboard and keep it in mind. Hannah mentioned something about cutting cardboard		
Jean	Who will buy your product? What are they into?	TP	ODE	1	SOPHISTICATION & FLEXIBILITY	Cardboard	T1_130519_M3 17:00	Whole class as thinking question	Willow: year 6		
Jean	Who will buy your product? What are they into?	TP	ODE	1	SOPHISTICATION & FLEXIBILITY	Cardboard	T1_130519_M3 17:09	William, Andy and Bao	If they are into beyblades, what can you do. Students talking simultaneously with multiple ideas. Teacher responds with yes..and encouraging sounds. She then tells them to put the ideas down. Stadium, storage place for beyblade (suggested by Jean). Tells William to write down 5 ideas. William keeps talking. Someone responds with hot wheels tracks. Jean responds "you are really thinking about your customers". How about hand soccer (foozball)?	Write down ideas	Brainstorm document
Jean	Does the product you designed have a purpose?	TP	BD	2	SOPHISTICATION & FLEXIBILITY	Cardboard	T1_130519_M3 min 32:20	Emily	Does not respond. Jean says she will chat about that		
Jean	Does the product you designed have a purpose?	TP	BD	2	SOPHISTICATION & FLEXIBILITY	Cardboard	T1_130519_A1 10:34, 19:56	Emily and Brooke	Emily: it is a toy Jean: it needs a purpose and it is quite safe design and to speak to Karalise. Emily: then shows something about clothes rack for the minion. Jean: explains that it is bit more creative and asks her to think more about the purpose and that decoration cannot be a purpose. E&B: come back and say they want to make a car and make it move. Jean: then asks them how will it move. E&B: When they suggest to put wheels and push it, Jean: suggests can they think of making it move without having to push it. She then suggests ballons or rubber-band powered car. She then asks them to research the ways they can move the car.	Made a huge car design	Rough plan
Jean	Does the product you designed have a purpose?	TP	BD	2	SOPHISTICATION & FLEXIBILITY	Cardboard			Jean asks them what they are making. G: They explain the basketball court. J: She asks for purpose. And then there non audible replies. She asks them to think more. G: To have fun. J: Jean says she is confused looking at the design. She says she needs to see some more detailed drawing and that she was not sure about the design. **She then asks what is the next step?** **G: Ava says - budget, advertising.** J: Jean says it is boring. She asks them to think more creative. G: Mila then suggests making a box and having fake audience inside the box. They then get into discussion about groups.	Mila and Ava decide to make dollhouse and Willow decides to make dollhouse	Rough plan
Jean	What is the next step?	TP	ODE	1	REFLECTION	Cardboard	T1_130519_A1 05:42, 14:45	Willow, Mila and Ava			

Appendix J - Sarah-Jane's Google slides for the unit

What do we need to do to be successful?

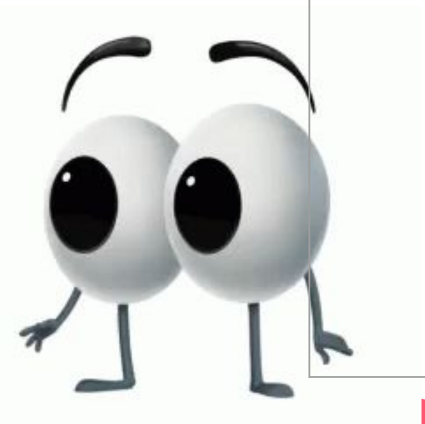
- Teamwork - sharing ideas , listening to all ideas before making a decision
- Self manager - making positive choices/ managing time
- Think - how are you going make it? How are you going to find a solution?
- Perseverance - Keep trying even when it's tough.
- Respect for others feelings and ideas.
- Challenge yourself.

Scenario

https://www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=12202937

Complete the table below

We noticed	We wonder



Your Mission

- Research filtering systems.
- Design a water filtering system to clean the water for the Hawes Bay residents.
- Build your prototype.
- Reflect on its success and make improvements.

Materials you will have access to:

2 coke bottles
netting
charcoal
sand
pebbles
cloth
dacron
anything you bring from home
coffee filters
wire

We know now	What we need to know

Answers to our wondering- place your research here

Labelled diagram of your plan

What materials will you need?

Explain the features of your filter

Questions to think about:

- Why have you used the materials you have chosen?
- How does your filtering system work?
- Have you missed anything out on your diagram?
- Will you need to test some of the materials you have chosen?

What challenges do you think you will face when building your prototype?

Photos of your learning journey

Test Your Bad Boy!

What adjustments have you found that need to be made to improve your water filter? Explain what and why you need to make them here. Add a plan and photo here.

Reflection - you need to create an iMovie reflecting on your learning today.

- How did you collaborate as a group?
- What skills have you used?
- What new learning have you experienced?
- What Challenges did you face and how did you overcome them?
- What wonderings do you have now?
- How will you use your new learning in the future?

Appendix K - Student groups at Athena

Student groups and technological outcomes in the Cardboard unit

Student/student groups	Technological outcome
Noah, Vijay, Dev	Foosball, Beyblade stadium and safe
Amelia, Willow	Picture frames and basketball court
Olivia	Candy holder shaped like a pig
Leo and Bao	Puppet show stage
Ruby, Mila, Ava	Dollhouse - toy
Harper and Ria	Minion stationary holder
Emily and Brooke	Minion car
George	Action figures - toy
Andy + 2 students	Robot - toy
William + 1 student	Hoop shooter game
Lucas and Sophie	Robot shaped stationary holder
Nicole and Isla	Pen holder

Note: The +1 student and +2 students indicate students for whom no parental consent was obtained. Their data is not included in the study.

Appendix L - Student groups at Minerva

Student groups in different lessons at Minerva

Lesson 1-2	Lesson 3 onwards
Ella	Ella
Nikau	Nikau+1
Jason+1	
Charlie,	Charlie,
Mia, + 1	Mia, Nur + 1
Dev,	Dev,
Aria + 1	Aria + 1
Ana + 2	Ana + 2
Blake,	Blake,
Amir,	Amir,
Sarah + 1	Sarah + 1
Aisha,	Aisha,
Kayla + 1	Kayla + 2
-	Zoe, Thomas + 1

Note: The +1 student and +2 students indicate students for whom no parental consent was obtained. Their data is not included in the study.

Appendix M - Student output at Athena

Outputs created by students at Athena

Lesson objective	Student output
Knowing about cardboard	Mind map of research on cardboard
Goal setting for the unit	Goals put up on the pushpin board in the classroom
Brain dump	List of things they could make out of cardboard
Making 4 concepts	Rough drawing of 4 concepts of the same idea
PMI	Three of the four concepts analysed with positive, negative, and interesting points
Survey questions	A word document with survey questions and options
Market research	Survey sheets filled up by talking to the consumer
Final selection	A rough drawing of the technological outcome
Modelling	Close-up view drawing; perspective drawing
Building the technological outcome	The final technological outcome
Logo design	Logo options; peer feedback on logo; final logo design
Poster designing	Poster plan; poster draft; final poster

Appendix N - Number of questions in each sheet of Iteration Round 1

Card name	Number of questions
CT/CTO Reflection Level 1-2	5
CT/CTO Transference Level 1-2	4
CT/CTO Socialisation Level 1-2	6
CT/CTO Resilience Level 1-2	2
CT/CTO Sophistication and Flexibility Level 1-2	14
CT/CTO Reflection Level 3-4	8
CT/CTO Transference Level 3-4	3
CT/CTO Socialisation Level 3-4	7
CT/CTO Resilience Level 3-4	4
CT/CTO Sophistication and Flexibility Level 3-4	9
BD/PP Reflection Level 1-2	4
BD/PP Transference Level 1-2	2
BD/PP Socialisation Level 1-2	4
BD/PP Resilience Level 1-2	4
BD/PP Sophistication and Flexibility Level 1-2	6
BD/PP Reflection Level 3-4	6
BD/PP Transference Level 3-4	6
BD/PP Socialisation Level 3-4	4
BD/PP Resilience Level 3-4	5
BD/PP Sophistication and Flexibility Level 3-4	8
ODE Reflection Level 1-2	6
ODE Transference Level 1-2	4
ODE Socialisation Level 1-2	5
ODE Resilience Level 1-2	7
ODE Sophistication and Flexibility Level 1-2	8
ODE Reflection Level 3-4	5
ODE Transference Level 3-4	3
ODE Socialisation Level 3-4	5
ODE Resilience Level 3-4	4
ODE Sophistication and Flexibility Level 3-4	5
TM/Tp Reflection Level 1-2	6
TM/Tp Transference Level 1-2	6

Number of questions in each sheet in Iteration 1

Card name	Number of questions
TM/Tp Socialisation Level 1-2	5
TM/Tp Resilience Level 1-2	3
TM/Tp Sophistication and Flexibility Level 1-2	11
TM/Tp Reflection Level 3-4	5
TM/Tp Transference Level 3-4	3
TM/Tp Socialisation Level 3-4	5
TM/Tp Resilience Level 3-4	3
TM/Tp Sophistication and Flexibility Level 3	5
TM/Tp Sophistication and Flexibility Level 4	7

Appendix P - Number of questions in each card in the final version

Card name	Number of questions
CT/CTO Reflection Level 1-2	5
CT/CTO Transference Level 1-2	4
CT/CTO Socialisation Level 1-2	6
CT/CTO Resilience Level 1-2	2
CT/CTO Sophistication and Flexibility Level 1-2	14
CT/CTO Reflection Level 3-4	8
CT/CTO Transference Level 3-4	3
CT/CTO Socialisation Level 3-4	7
CT/CTO Resilience Level 3-4	4
CT/CTO Sophistication and Flexibility Level 3-4	9
BD/PP Reflection Level 1-2	4
BD/PP Transference Level 1-2	2
BD/PP Socialisation Level 1-2	4
BD/PP Resilience Level 1-2	4
BD/PP Sophistication and Flexibility Level 1-2	6
BD/PP Reflection Level 3-4	6
BD/PP Transference Level 3-4	6
BD/PP Socialisation Level 3-4	4
BD/PP Resilience Level 3-4	5
BD/PP Sophistication and Flexibility Level 3-4	8
ODE Reflection Level 1-2	6
ODE Transference Level 1-2	4
ODE Socialisation Level 1-2	5
ODE Resilience Level 1-2	7
ODE Sophistication and Flexibility Level 1-2	8
ODE Reflection Level 3-4	5
ODE Transference Level 3-4	3
ODE Socialisation Level 3-4	5
ODE Resilience Level 3-4	4
ODE Sophistication and Flexibility Level 3-4	5
TM/Tp Reflection Level 1-2	6
TM/Tp Transference Level 1-2	6

Number of questions in each card in the final version

Card name	Number of questions
TM/Tp Socialisation Level 1-2	5
TM/Tp Resilience Level 1-2	3
TM/Tp Sophistication and Flexibility Level 1-2	11
TM/Tp Reflection Level 3-4	5
TM/Tp Transference Level 3-4	3
TM/Tp Socialisation Level 3-4	5
TM/Tp Resilience Level 3-4	3
TM/Tp Sophistication and Flexibility Level 3	5
TM/Tp Sophistication and Flexibility Level 4	7

Appendix Q - Consent form samples

Consent form of Principal

Faculty of Education
Te Kura Toi Tangata
The University of Waikato
Private Bag 3105
Hamilton, New Zealand

THE UNIVERSITY OF
WAIKATO
Te Whare Wānanga o Waikato

Consent Form for Principal

Research title: Exploring the effects of classroom interactions on teachers and students' learning in technology education in primary classroom

Researcher: Swathi Rangarajan

In signing this form, I acknowledge that:

- I have been given an explanation of the research project.
- I have had an opportunity to ask questions and have them answered.
- This form will be held for five years. The data gathered will be kept securely for the same length of time.
- I understand that the teachers, parents and students can withdraw at any time during this project until one month after the completion of the two units.
- I understand that all attempts will be made to keep all participants' names and the school name anonymous, but anonymity cannot be guaranteed due to use of videos and photographs in dissemination of the research.
- I give permission to the investigator for:
    - Working with the teacher in planning and executing two technology units through the year 2019
    - Collecting relevant data related of the classrooms in form of photographs, audio and video provided consent is obtained from teachers, parents and students
    - Contacting the parents of the students in the specific classrooms.

The teacher(s) who will be working in this project is [redacted] from [redacted]

Name of the school: [redacted]

Name of the Principal: [redacted]

Signature: [redacted]

Date: 7/3/19

This research has been approved by the University of Waikato Faculty of Education Ethics Committee on 8 November 2018. Approval number: FEDU082/18

Consent form of Teacher

Faculty of Education
Te Kura Toi Tangata
The University of Waikato
Private Bag 3105
Hamilton, New Zealand

THE UNIVERSITY OF
WAIKATO
Te Whare Wānanga o Waikato

Consent Form for teachers

Research title: Exploring the effects of classroom interactions on teachers and students' learning in technology education in primary classroom

Researcher: Swathi Rangarajan

In signing this form, I acknowledge that:

- I have been given an explanation of the research project. I have had an opportunity to ask questions and have them answered
- This form will be held for five years. The data gathered will be kept securely for the same length of time.
- I consent to plan two units of technology in the year 2019 and execute the units using the Technology Observation and Conversation Framework
- I understand that all attempts will be made to keep all participants anonymous, but anonymity cannot be guaranteed due to use of videos and photographs in dissemination of the research.
- I give permission to the investigator for:
  - Audio, video recording and photographing my technology classrooms
  - Collecting relevant data related to the classrooms in form of photographs
  - Collecting unit planning documents, photographs of classroom teaching aids and feedback given to students
- I understand that I can withdraw any data provided at any time until one month after the final transcripts being provided to me.

Name of the teacher: [redacted]

Year level: 5 - 6 Classroom number: [redacted]

Number of students in class:

Boys: 13 Girls: 13

Ethnic makeup of class:

NZ maori: 3 European: 14 + 1 Asian: 6 Pacific island: 1 Others: 1

Signature [redacted] ↑ SR Date: 26/3/19

This research has been approved by the University of Waikato Faculty of Education Ethics Committee on 8 November 2018. Approval number: FEDU082/18

Consent form of Parent

Faculty of Education
Te Kura Toi Tangata
The University of Waikato
Private Bag 3105
Hamilton, New Zealand

THE UNIVERSITY OF
WAIKATO
Te Whare Wānanga o Waikato

Consent Form for parents

Research title: Exploring the effects of classroom interactions on teachers and students' learning in technology education in primary classroom

Researcher: Swathi Rangarajan

There are two consent forms: please fill in the appropriate one.

Full consent

In signing this form, I acknowledge that:

- I understand the main aim of the research project and understand that I can withdraw my permission at any time.
- This form will be held for five years. The data gathered will be kept securely for the same length of time.
- By signing this form, I consent to allow the researcher to observe, record (audio and video) and take photographs of my child and my child's work in the technology classroom.
- I understand that all attempts will be made to keep all participants anonymous, *but anonymity cannot be guaranteed due to use of videos and photographs in the published research*

Name of the parent: [redacted]

Name of the student: [redacted]

Name of the teacher: [redacted]

Year level: 5 Classroom number: R14

Signature: [redacted] Date: 19/3/2019

This research has been approved by the University of Waikato Faculty of Education Ethics Committee on 8 November 2018. Approval number: FEDU082/18

Consent form of Student

Faculty of Education
Te Kura Toi Tangata
The University of Waikato
Private Bag 3105
Hamilton, New Zealand

THE UNIVERSITY OF
WAIKATO
Te Whare Wānanga o Waikato

Consent Form for students

Research title: Exploring the effects of classroom interactions on teachers and students' learning in technology education in primary classroom

Researcher: Swathi Rangarajan

By signing or writing my name, I agree that you can:

- [x] Observe me, talk to me and you can take my photos and videos and also of my work in the class
- [ ] Observe me, talk to me but DO NOT take my photo or video. You can take photo of my work in the class
- [ ] I do not want to participate

Name of the student [redacted]

Name of the teacher: [redacted]

Year level: 6 Classroom number: [redacted]

Signature: Date: 30.5.19

This research has been approved by the University of Waikato Faculty of Education Ethics Committee on 8 November 2018. Approval number: FEDU082/18