Developing, fostering, and enriching young children's STEM related working theories: Mediating influences and models

Daniel Lovatt

A thesis submitted in fulfilment of the requirements for the degree of Doctor of Philosophy in Education, the University of Auckland, 2020

Abstract

The early years is a critical time for learning. During this time, the development of knowledge, skills, and attitudes provide foundations for a lifetime of learning. Knowledge, skills, and attitudes combine to form working theories, a notion that is central to this thesis, and which originated in early childhood education in Aotearoa New Zealand. Working theories are children's tentative and evolving ideas and understandings about the world, and are a key outcome of the New Zealand early childhood curriculum Te Whāriki. Understanding how children develop working theories, and teachers' roles in that development is therefore essential.

This thesis aimed to investigate the development of working theories about science, technology, engineering and mathematics (STEM), and the associated teaching approaches that fostered and enriched that development. Two original and innovative models were created to explain the findings of this thesis: the spiral of working theory development which represents how children developed their working theories; and the shared learning commitment model which represents how teachers fostered and enriched that development.

This interpretivist, qualitative study drew on ethnographic approaches to investigate the case: young children's developing working theories. Data were generated during seven months of field work in two early childhood education centres in Auckland, New Zealand through participant observations, semi-structured interviews with teachers, and by recording centre documentation. Data were analysed using thematic analysis and with the two models used as dynamic, interpretive frameworks. The models were developed and refined through the complex and iterative process of melding literature, theory, data and findings.

This thesis argues that the sociocultural notion of mediation is critical to working theory development. First, teachers' knowledge, skills and attitudes toward STEM mediate their involvement in STEM related teaching and learning experiences. Second, working theories act as a framework through which new information is passed. Therefore, working theories can be viewed as mediators of new information. Third, teachers' understandings of concepts and children mediate their involvement in teaching and learning about STEM.

This thesis therefore offers new and innovative insights and understandings into working theory development and associated teaching approaches that hold important implications both for teachers and for further research that could transform children's learning.

Acknowledgements

Ehara taku toa, he takitahi, he toa takitini

My success should not be bestowed onto me alone, as it was not individual success but success of a collective. (Mead & Grove, 2001)

The doctoral journey is potentially a lonely one. Yet, my doctoral journey has certainly not been lonely. I have been supported throughout this intense but enjoyable process by my family, supervisors, participants, and friends. As the whakatauki above says, my success is indeed the success of a collective. I thank you all.

First and foremost, I wish to acknowledge the influence, support, and encouragement of my father Dennis. We continue to search for the lost photograph which shows him, my three-year-old sister, and four-year-old me together using one saw to cut pieces of wood that were used to build the family house. Your warmth, pedagogy, patience, and attention to detail inspired me throughout my doctoral process.

To my wonderful supervisors Professor Helen Hedges, Dr. Rena Heap, and Dr. Gillian Ward, your wisdom, dedication, rigour, care, and generosity enabled this to be a challenging yet enjoyable process. To Professor Elizabeth Wood, thank you for your advice, time, and encouragement. I would also like to acknowledge the University of Auckland for funding much of my study through a doctoral scholarship.

To the leaders, teachers, children, and families in this study, I wish to say an enormous thank you. You let me into your settings, shared your lives with me, and inspired me through the ways you taught and learnt. I need to also thank my friends and colleagues Maria Cooper, Joanna Williamson, Tamar Weisz-Koves, Amanda White, Penny Lee, and the A block doctoral hub students for your friendship, your interest, for listening, offering advice, and for your humour.

I would also like to acknowledge and sincerely thank my daughter Ali who initially inspired my move into early childhood education. Thank you for your love, unending support, your interest in my work, and for the way you kept me grounded and on track. Marisa and Aly, I also give you my heartfelt thanks for your unending support, advice, interest, and love. This would not have been possible without you.

Finally, to my greater family, and especially to Joe and Delia Jobst, I also say a great big thank you. Thank you for taking an interest, for supporting me and encouraging me.

Table of contents

1. Setting the scene

E kore e taea e te whenu kotahi ki te raranga i te whāriki kia mōhio tātou kiā tātou. Mā te mahi tahi ō ngā whenu, mā te mahi tahi ō ngā kairaranga, ka oti tēnei whāriki.

The tapestry of understanding cannot be woven by one strand alone. Only by the working together of strands and the working together of weavers will such a tapestry be completed. (Kūkupa Tirikatene, 2013)

Remember when?

Can you remember learning to throw a ball? The seemingly simple action of throwing requires coordination, and at some point, intense focus and attention. During this time, working theories (Ministry of Education [MOE], 2017)—which can be thought of as tentative and evolving ideas and understandings—are being formed (I explain the notion of working theories in depth later in this chapter). But working theories are not just being formed, at the same time those developing working theories are being used. From first watching a ball being thrown, working theories are developed about how to throw a ball. These initial working theories might be that the ball must be held in your hand, and that your hand and arm must be projected forward, and that your fingers must open at some stage. You may then have a working theory that as you do those actions, the ball will leave your hand and travel forward. As you throw the ball, your working theories will likely develop and perhaps become refined through information gained from the experience. The process of throwing might provide information that many more muscles than just those in your arms and fingers are required as you twist your body, push with your toes, rotate your hips and use your other arm for aiming and momentum. Your working theories about throwing likely became broader and deeper by incorporating the new information from these experiences.

In this thesis, I argue that working theories develop through new and further experiences. New information is incorporated into existing understandings which leads to the development and/or refinement of knowledge, skills and attitudes. Working theories never reach a point of perfect knowledge, skills and attitudes. They continue to develop over a lifetime, for instance learning new ways to throw and aim, and setting new goals. Furthermore, over time understandings about the world change, leading to further development and refinement of working theories.

Working theories about throwing encompass the STEM domains (science, technology, engineering and mathematics). These working theories could include scientific concepts such as gravity and energy; technological understandings such as making and using targets to aim; engineering concepts of problem solving, trialling and evaluating; and mathematical concepts such as parabolic flight paths. A common, seemingly simple, yet extraordinarily complex experience such as throwing a ball is one example of everyday experiences in early childhood education (ECE) centres that potentially foster and enrich young children's working theories about the STEM domains. STEM education provides the contextual focus for this research about the development of working theories.

Working theories are the focus of a growing research and literature base both in New Zealand and internationally. This thesis sets out to add to this base by investigating how working theories about STEM are developed, fostered and enriched in ECE settings. As the whakataukī (Māori proverb) at the beginning of this chapter says, this thesis aims to add strands to understandings, both about the notion of working theory development, and how they might be enriched.

Outline of the thesis

In this thesis, I identify, position, justify and address three supporting research questions, and an overarching research question in a different way to most conventional theses. A single literature review and single findings chapter have not been included. Instead, literature review and findings sections that address each of the three research questions are presented in chapters 3-5. Consistent with this approach, chapter 6—which explains and theorises the findings—also has a separate literature review critiquing literature relating to the theoretical underpinnings of this thesis. Because of the unconventional approach, this introductory chapter is longer than a typical thesis as it includes definitions for constructs and notions that are common across chapters 3-6, the research questions, and the conceptual framework. The main motivation behind this approach is to have chapters 3-6 set up towards future publication.

Initially, at the commencement of the doctorate, I conducted a separate critical literature review. During this time, I identified the research space, scope, rationale for the research, and developed the research questions. Following the decision to set chapters 3-6 up for future publication, the literature review was rewritten to address the three research questions separately. As writing progressed, a decision was made to provide a separate methodology

chapter—chapter 2—but to retain separate literature review sections for chapters 3 to 6. This format enabled a clear methodological chapter to be written, while enabling individual, concise literature reviews, findings, and discussion sections that addressed the focus of chapters 3-6.

The thesis is structured as follows. In chapter 1 which is this introduction, I identify a rationale and space for the research topic. I describe how I became a working theories researcher, then explain my epistemological stance and the conceptual framework used. Next, I explain the research context which is ECE in New Zealand. I then explain the contextual focus of the research which is STEM, and present research question 1. Following this, I overview working theories, introduce research question 2, and justify the place of working theories internationally. I then outline the teacher's role in fostering and enriching children's working theories and introduce research question 3. Next, I explain the theoretical construct of mediation as underpinning the findings and introduce the overarching research question. Finally, I recap the research questions and summarise the chapter. In chapter 2, I explain and justify the interpretivist, qualitative case study methodology of this research. I then explain my positioning as researcher before describing the nature of this research as a case study drawing on ethnographic approaches. Next, I describe the settings, and the participants before explaining the methods used to generate and analyse data. I explain the development of two models—the spiral of working theory development, and the shared learning commitment (SLC)—which were created and refined during this research. I finish chapter 2 by explaining ethical considerations and issues of trustworthiness.

As I have already described, chapters 3, 4, and 5 each incorporate a literature review, findings, and discussion section relevant to the research question which the chapter is addressing. Chapter 3 critically examines teachers' perceptions of STEM education within ECE contexts. In this chapter, I present a rationale for STEM education within ECE contexts, review relevant literature on STEM in ECE, and present findings which focus on teachers' understandings of STEM, teacher views that STEM is everywhere, and that there are many areas of learning in ECE to focus on. Chapter 4 focuses on young children's development of working theories. I argue a rationale for a focus on working theories in ECE, then review relevant literature, working towards the presentation of the spiral of working theory development model as one way to explain how working theories were developed, enriched and refined. In chapter 5, I focus on teaching approaches that foster and enrich young children's working theories. After reviewing relevant literature, again, I present a model developed during the research—the

SLC—as an explanation of the ways teachers work with children to develop their working theories.

In chapter 6, I add a theoretical layer to theorise the findings using the sociocultural notion of mediation. I explain the construct of mediation for this research, argue a rationale for its use, and then address the findings of research questions 1, 2, and 3 using a mediational perspective. I then weave the theoretical explanations which address research questions 1, 2 and 3 together to address the overarching research question: How might STEM related working theories be developed, fostered and enriched in early childhood education settings.

Chapter 7 concludes the thesis. In this chapter, I summarise this study, and highlight the original contributions and new findings that this research has made. I then offer implications, recommendations, and my thoughts about further research which could result from this study.

It is important to explain and justify a rationale for this research. I do this next.

Rationale

The early years is a time of vast potential learning. Studies have shown that positive early learning opportunities benefit children's ongoing knowledge, skills, attitudes, and wellbeing (Organisation for Economic Co-operation and Development, 2012; Sylva & Roberts, 2010). Research in Aotearoa New Zealand aligns with these findings, highlighting positive outcomes from quality ECE (Wylie, Hogden, Ferral, & Thompson, 2006).

The New Zealand educational system has been criticised as prioritising skills and competencies over knowledge (Hood et al., 2018). This priority is likely driven by a perceived view that skills and competencies are required for future employment, an understanding that the world is changing quickly, and because the notion of knowledge has become pluralistic. This priority can be seen in the foreword of the Aotearoa New Zealand early childhood curriculum *Te Whāriki* (MOE, 2017) which "positions our children as 21st century citizens, learning how to learn in a fast changing and globally connected world." (p. 2). Left unchecked, and as a worst-case scenario, the focus on skills and competencies could result in children becoming "self-confident fools" (Bruner, 1977. p. 65), having great confidence in their ability to learn, but holding little knowledge or understanding.

Curriculum in ECE is a contentious space. It has typically been a space where learning processes are foregrounded. Recently however, demands have been made for ECE curriculum

to focus on school readiness and to be a place for educational policies to be enacted (Wood & Hedges, 2016). Therefore, there is a tension between focusing on learning processes such as skills and competencies, and a demand to focus on academic objectives such as knowledge and content. I argue that the notion of working theories could resolve this dilemma. This notion is an interweaving of knowledge, skills, and attitudes, and a specific learning outcome in *Te Whāriki*, as I explain later in this chapter. This thesis focuses on the notion of working theories, taking an holistic perspective of learning and therefore transcending the debate between skills and competencies versus knowledge and content. This research builds on prior working theory research by investigating how young children develop working theories, and the ways that teachers might foster and enrich that development, focusing on the context of STEM.

STEM education is an area of growing interest, focus and funding both internationally and in New Zealand. The rationale for the interest, focus and funding is centred on economic and global success (Marginson, Tytler, Freeman, & Roberts, 2013; Ministry of Business, Innovation and Employment [MBIE], 2014). Yet STEM education provides more than positive economic outcomes.

STEM education can lead to holistic understandings of the world as an enormously complex and interconnected place. People with understandings about the STEM domains are likely to better understand the complexities that the world is facing, enabling better decision making about complex issues such as climate change (Bybee, 2013). Research highlights that developing understandings and positive attitudes in the early years influences ongoing achievement, efforts and attitudes throughout later schooling (Bybee, 2013; Linder, Powers-Costello, & Stegelin, 2011; Wylie et al., 2006; Zucker et al., 2016). A positive and affirming introduction to STEM could therefore provide a foundation for ongoing interest and learning throughout a person's life. Furthermore, STEM education need not be purely future focused. It can provide knowledge, skills, and attitudes needed in a person's, and in the case of this research, in a child's daily life.

ECE provides ideal contexts for teaching and learning about STEM. In New Zealand, ECE settings are typically play-based where children aged between birth and six-years-old self-select their activities and experiences (White et al., 2009). Spontaneous STEM related teaching and learning opportunities abound. This research sets out to investigate those opportunities.

This thesis explores the teaching and development of young children's working theories in the context of STEM learning. This research builds on prior research that explores young

children's working theories by focusing on ways that working theories about STEM are developed and refined by young children, and how teachers foster working theory development. The research adds to existing research about working theories by representing the development of working theories as a model—the spiral of working theory development—and representing the associated teaching approaches as a model—the SLC. In addition, the findings of this research could inform policy, practice, and funding as I argue in chapter 7. The research then forms a critical part of understanding teaching and learning in ECE.

This thesis therefore presents research investigating how children developed working theories about STEM, and ways that teachers fostered and enriched this development. To do this, an overarching research question and three supporting questions were developed, addressed, and answered. I present these research questions throughout this chapter. But first, I explain my story of becoming a researcher, my epistemological stance and associated conceptual framework.

Becoming a working theories researcher

This section briefly describes the story of how I came to be researching young children's working theories. I do this to provide transparency to this study by explaining the background to my epistemological stance and the conceptual framework which are the next parts of this chapter. I describe my background, career and interest in young children's working theories. In chapter 2, I build on this story to explain my positioning as a researcher.

My father left school at 15 and began working as an apprentice electrician. Fifty years later, he retired from his role as an electrician. He lived in an era where it was acceptable and expected that the workforce chose and remained in one career for their lifetime. Like my father, my career began as an electrician. However, society is constantly changing as a result of historical, political, social and cultural changes. In my era it is acceptable, and perhaps expected, that a career is no longer life-long. I have adhered to the new expectation, having worked as an electrician, consulting engineer, electrical engineer, early childhood teacher, and doctoral student. All of these stages in my working life have influenced my doctoral study.

I often reflect over my education and wonder how well it prepared me for the world I now live in. Could I have been better prepared to understand and contribute to this world? Undoubtedly, the world has changed, and been recognised as significantly more complex, and interconnected since my early schooling. Many scientific truths I was taught are now seen as tentative and

evolving, debatable and contextual. This realisation has led me to perceive learning as a combination of knowledge, skills and attitudes that are sufficient to explain the world as I perceive it, but also as a combination or knowledge, skills and attitudes that enable me to critique existing knowledge, and seek out further knowledge and understandings.

Much of my tertiary education has focused on complex mathematics with underlying assumptions that it could not be applied to real-world contexts due to further complexities and anomalies. I wondered about the reason for this learning. Furthermore, most of my work-related knowledge and skills were actually gained on-the-job, often revisiting past on-the-job skills and building on them. Those thoughts influenced my doctorate in that I view that a mixture of theoretical and real-world learning and experiences can provide the knowledge, skills and attitudes needed to understand and contribute to the world.

My experiences as electrician and engineer influenced my thinking about teaching, young children's learning, and the design of this thesis. During that time, I undertook my Bachelor of Engineering part-time, mixing work and study. These were times where my learning, thinking and work emphasised logic and structure. To be successful, I planned carefully, and strived for excellence. Years later, I still recognise the importance for young children to plan, evaluate and use logic in their play and learning in ECE. However, the world of ECE teaching opened me up to a wider appreciation of teaching and learning.

My early childhood teaching experiences have helped me to develop my thinking for this thesis. I often marvel at the way young children take resources and materials and use them ingeniously. I have spent much time listening and talking with children, being constantly amazed by their thinking, logic, and creativity. I still recognise the significance of logic and structure in teaching and learning, but embrace the importance of creativity and imagination. Therefore, I value the importance of logic, structure, imagination and creativity in both children's learning and in the design of this thesis.

While working as an ECE teacher, I was also involved as a teacher-researcher in a large-scale Teaching and Learning Research Initiative (TLRI) project (Hedges & Cooper, 2014a). At the same time, I undertook a Master of Professional Studies. This was a time when I focused on children's working theories, both as part of the TLRI, and as part of my Master's research. During, and since this time, I have continued to think, reflect, critique, publish and present about working theories. My publications related to working theories include Cooper, Hedges, Lovatt, and Murphy (2013); Lovatt and Hedges (2014); Lovatt (2014); Lovatt and Hedges

(2015); Cooper, Lovatt, and Hedges (2015); Williamson, Lovatt, and Hedges (2020). I have also presented numerous times to the ECE sector about working theories and have gained rich insights about working theories from conversations and feedback with the participants. Over time, I have come to recognise the richness of interpretive, qualitative research, and the multiple lenses that can be used to view working theories. I saw that there was significant complexity involved in the development and teaching of working theories. I believe that this time had a profound influence on the design of this thesis. In addition, I believe that period also enabled me to embrace the complexity of working theories which is reflected in this thesis.

Becoming a working theories researcher has therefore been a life-long process. Influences throughout my lifetime have shaped the design of this thesis, my lens that I have used, and my views about the development, enrichment and teaching involved in working theory development.

As I stated in the beginning of this section, it is important for me to explain my journey to becoming a working theories researcher. This research uses an interpretivist paradigm as I explain in chapter 2. Therefore, I interpret the research design and process differently to others. My experiences as electrician, engineer, ECE teacher, and academic mean that I bring a unique mix of interest, motivation, experience, knowledge, expertise, and perspective to this research.

An epistemological stance

> "Knowledge is always in a process of becoming; it is always being reshaped and reconstructed as the students' cognitive capacities change, adapt and develop to accommodate new and unique experiences" (Magrini, 2010, p. 15)

A researcher's epistemological stance influences their research subject, methodology and methods. Therefore, it is important to explain my epistemological positioning in regards to this research. The thoughts of Magrini (2010), which I used to begin this section, sum up my stance succinctly. These thoughts describe both the research process for me, and my perspective on knowledge for this thesis. This thinking has influenced my methodological framing which I explain in chapter 2, and my conceptual framing which I explain in the next section.

My background which I described earlier, shaped my epistemology. As an electrician, and then as an electrical engineer, my role was to provide best solutions for problems. Often this meant operating in a positivist epistemological world of black and white, where there was one answer

uncovered through rigorous work. Two factors shook my epistemological understandings: First, the move into teaching introduced me to an interpretivist world of varying grey shades. My epistemological understandings were shaken as I recognised that there were multiple, perhaps endless possibilities, and that all might have relevance. Second, at the same time, as I read more about science and technology, I came to realise that some of the scientific truths that I had been taught at school were changing. The so-called truths were actually scientists' best hypotheses based on the information they had at the time. New information was leading to modified hypotheses. These two factors led to me embracing an interpretivist epistemological world, although I am tempted at times by the definite black and white leanings of my past. My teaching career then was full of wonderings and reflections about the children, their families, and my role in the teaching and learning that I engaged in.

I bring these epistemological understandings, wondering and reflection to this research. The nature of teaching and learning in ECE is highly complex. There is no such thing as definite right or wrong answers. We all bring relevant, but differing views about the world. Recognising my epistemological view, and the importance of research questions being reflexive and dialogic (Agee, 2009) means that my research questions all begin with "how might". These two words recognise that I bring my perspective to this research, and that other perspectives may be equally valid. My views also mean that my focus is not on conceptual accuracy of working theories. Instead, my focus is on the formation and enrichment of working theories. Scientists base their theorising on the best and latest information they have. In a similar way, I believe that children form and enrich their working theories based on their best and latest information. Sometimes children's working theories can be difficult to shift, perhaps because they consider the original source to be irrefutable: "because my mum says so!". Similarly, I wonder if scientists might hold onto working theories in the face of conflicting evidence "because Einstein says so!".

I view knowledge as dynamic, and in a state of flux, in a similar fashion to working theories which are described as tentative and evolving understandings (MOE, 2017). Therefore, for this research, I view knowledge as a context and time oriented construct. In particular, I view knowledge developing and changing through social, cultural and historical influences. My view raises an important point: can my research provide any knowledge of value or worth if it is in a constant state of flux and in a specific context? I argue that this research can. Within the social, cultural and historical context that I am researching, there is a real, knowable world potentially transferable to other contexts (Braun & Clarke, 2013). In addition, society, culture

and technology are changing, but the change is not instantaneous. Findings from this research will be valid for a time. As time passes, historical knowledge such as the knowledge generated from this study will be informative and useful just as prior research has informed this study.

My epistemological stance has informed my conceptual framework. I explain the framework next.

Conceptual framework

A conceptual framework brings together the multiple formal theories which underpin the research process in a cohesive way (Ravitch & Riggan, 2012). It informs, guides and provides a rationale for the many stages and decisions that are made throughout the research. It is important to be transparent about my conceptual framework to enable my perspective and underlying beliefs to be understood by the reader, which I do next.

In short, my conceptual framework brings together sociocultural and social constructivist theories within an interpretivist paradigm. Literature is inconsistent about the definitions of these theories and paradigm. Therefore, it is important to provide an explanation of them and describe how they are applied in my research. I do this in the next sections.

An interpretivist paradigm acknowledges that people engage in, interpret and give meaning to real-life experiences (Merriam & Tisdell, 2016). This means that there are multiple ways to view or interpret the world. In other words, everyone sees things slightly differently. The paradigm involves searching for "*culturally derived and historically situated interpretations of the social-life world*" (Crotty, 1998, p. 67). Two common terms throughout the literature related to interpretivist approaches are meaning-making and understanding (Blaikie, 2004; Crotty, 1998; Stelmach, 2016). An interpretivist lens means that people are constantly interpreting the world seeking to understand and make meaning of it. The meanings, understandings and therefore the interpretations are necessarily different for each individual. This view is critical to my research as it then means that every teacher will have different interpretations of their role, and every child will have different interpretations of the world.

A sociocultural theoretical lens provides the second aspect of my conceptual framework. A sociocultural view of teaching and learning acknowledges that people learn in, and cannot be separated from cultural, social and historical contexts (Wertsch, 1991). This approach recognises the importance of contact, creation and interaction with people's surroundings

(Cole, 1996; Daniels, 2015; Kozulin, 2003; Wertsch, 2007). For this research, the surroundings are the two participating ECE settings which are a product of culture, society and history. The settings have been and continue to be shaped by the participants—the teachers and children—of this research. In addition, the settings have been shaped by past children, and former teachers. Thus, the surroundings are a product of social, cultural and historical influences. My research focuses on the contact, creation and interactions with the surroundings at two levels: First, the environment and experiences that are provided by teachers and undertaken by the children and the associated exchanges that occur. Second, the simultaneously occurring change to the environment and experiences that occurs because of the children's and teachers' interactions. I have sought to describe, explain and understand the actions of the teachers and children within these cultural, social, and historical ECE settings to address the research questions.

A social constructivist theoretical perspective is the third aspect of the conceptual framework. It both aligns with, and provides a perspective to understand interpretivism by highlighting the background of the individual and its influence on their interpretation and understanding of the world. Social constructivism is closely related to sociocultural theory, with a subtle, but significant difference between the two perspectives. A sociocultural lens foregrounds the social and cultural contexts in learning, whereas social constructivism foregrounds individual learning which is mediated through relationships and interactions (Rogoff, 1998). Social and cultural influences are still an important aspect of social constructivism, as relationships and interactions are necessary social, and are affected by culture. As social constructivism adds a social layer to constructivist approaches, I discuss constructivist approaches next, before moving on to explain social constructivism further.

From a constructivist perspective, individuals each construct subjective meanings of experiences (Creswell & Creswell, 2018). Constructivism focuses on using existing understandings to form meaning of new experiences and contexts (Applefield, Huber, & Moallem, 2000; White, 2011). Individual meaning-making using prior understandings is then at the centre of constructivist views. Similar to interpretivism, a constructivist approach acknowledges that individuals will each form different understandings of the same experience because their prior experiences and understandings are different. Social constructivist approaches acknowledge social influences on constructivism and is what I discuss next.

The social constructivist approach builds on constructivism to encompass the social influence in meaning-making. Meaning is made through interactions with a human community. Social constructivism is attributed to Vygotsky who first emphasised the social influence in learning (Vygotsky, 1978). Of particular importance to this research, social constructivism views students learning through interactions with other people and with objects in social contexts. Therefore, there is a strong correlation between sociocultural and social constructivist theories.

For this research, social constructivist and sociocultural theoretical perspectives weave together under the interpretivist paradigm. Interpretivism means that multiple meanings can be made from any experience or situation. Social constructivism focuses on an individual's construction of meaning by using their prior understandings, and through relationships and interactions with people. A sociocultural view focuses on the mediation of understandings through social and cultural influences. Drawing these three aspects together means that individuals use their existing understandings to construct unique, new or enriched understandings from new experiences that occur in a social and cultural setting. The new experiences occur through interactions with people, objects, materials, resources, and the environment in ECE contexts.

The conceptual framework represents and guides two key areas of this research: my epistemological and methodological perspectives. Epistemologically speaking, I see young children as bringing a richness of experiences and dynamic understandings with them to their ECE contexts. Over time, and through new experiences, they refine and enrich their understandings. These understandings are different for every child, and every experience is then interpreted differently by every child, meaning that every child holds different understandings. Methodologically speaking, and as I explain in chapter 2, the conceptual framework has shaped my research design. I acknowledge that I form my own interpretation of this research, from my research questions, to the literature I read, to the way I have approached data gathering and analysis and theorising, to the way I have written this thesis.

My conceptual framework aligns with prior research on working theories, and about STEM education. From a constructivist perspective, prior working theory and STEM education research acknowledge that children make their own individual meanings of the world (Hedges, 2011; Lindeman, Jabot, & Berkeley, 2013). Prior research on working theories has also used a sociocultural approach (Davis & Peters, 2011; Hedges & Cooper, 2014). Roth and Eijck (2010) argued that STEM education should be taught, learnt and researched within a broad

sociocultural framework that takes into account learning across time. Furthermore, prior research into STEM education has been undertaken using a sociocultural approach focusing on children's meaningful experiences (Kumtepe & Genc-Kumtepe, 2015). My research draws on, and weaves these approaches together.

As Ravitch and Riggan (2012) stated, the conceptual framework evolves dynamically throughout the research process. This has certainly been the case. The framework has developed from a largely constructivist perspective to one which weaves together interpretivist, sociocultural, and social constructivist approaches. These theoretical perspectives have been used in prior working theory and STEM research but not all together. This research therefore provides a new and unique conceptual framework to investigate working theories and STEM education, providing a new perspective on ways children develop working theories and how teachers foster working theory development.

In chapter 2, I draw on this section about my conceptual framework to describe, explain and justify the methodology I have used for this research. I now move away from the underpinning frameworks of this research to describe the general context of ECE in New Zealand.

The New Zealand ECE context

New Zealand ECE is recognised as a diverse landscape (Tyler-Merrick, Phillips, McLachlan, Aspden, & Cherrington, 2018). Contexts range from teacher-led (for instance education and care services, kindergartens and home-based services) to parent-led (for instance playcentres). Within this diverse landscape, the approaches to teaching and learning vary along a spectrum from free-choice, play-based teaching and learning to adult-led, didactic teaching (Smith, 2013). Therefore, ECE in New Zealand involves diverse contexts and diverse philosophies of teaching and learning.

In New Zealand, children can attend ECE from birth to six years. The New Zealand government fully subsidises 20 hours per week of ECE for 3, 4, and 5-year-olds in licensed ECE services (MOE, 2018). Fees are charged by the ECE services for longer attendance. Minimum adult/child ratios are set by the government and depend on the physical size of the centre, the length of time the centre is open each day, the age of the children, and whether different age groups are mixed together or separated (New Zealand Government, 2018). Fifty percent of the teachers in an ECE centre must hold a recognised early childhood teaching qualification (New Zealand Government, 2018). Since 1996, New Zealand early childhood education has been

guided by the curriculum framework *Te Whāriki*. I provide a brief overview of this curriculum next.

Te Whāriki (MOE, 1996, 2017) is a bicultural curriculum reflecting the commitment to partnership between Māori (the original inhabitants of New Zealand) and New Zealanders of European descent, referred to as Pākehā. (Ritchie & Skerrett, 2014). *Te Whāriki* is a philosophical, non-prescriptive document recognising children as competent, capable and confident.

Multiple theoretical perspectives can be used to view and interpret *Te Whāriki*. For my research, as I have explained, sociocultural and social constructivist theories are key theoretical perspectives of my conceptual framework. Both theories are valid ways of interpreting *Te Whāriki* as I explain next.

Sociocultural theories are highlighted in *Te Whāriki*, in particular, those of Vygotsky and Bruner (MOE, 2017). Furthermore, the sociocultural concept of mediation—a key theoretical aspect of this thesis—is noted in the section on sociocultural theories: learning is "mediated by participation in valued social and cultural activities." (MOE, 2017, p. 61). Mediation is also indirectly referred to throughout the curriculum document, through wording which highlights the importance of social interactions, materials, artefacts, tools, signs and symbols for children's learning (MOE, 2017).

Social constructivist theories are not mentioned explicitly in *Te Whāriki*, but can be inferred throughout the document. As already noted, social constructivism foregrounds individual learning which is mediated through relationships and interactions (Rogoff, 1998). From a social constructivist perspective, past experiences and understandings are used to make sense of new experiences. The importance of experiences is noted multiple times in *Te Whāriki* which highlights the importance of children's knowledge and past experiences as providing a foundation for learning. As I describe later in this chapter, working theories, which are an overarching outcome of *Te Whāriki*, and a key aspect of this thesis, are described as developing as children use their existing knowledge to make sense of new experiences (MOE, 2017).

Therefore, sociocultural and social constructivist perspectives are consistent with the ECE curriculum in New Zealand. Together, these perspectives highlight social and cultural activities, knowledge and past experiences as influencing children's learning. These perspectives provide insights into the curriculum which I explain next.

Te Whāriki is a Māori word meaning woven mat. To construct local curriculum, principles, strands, goals and learning outcomes from the curriculum document are woven together. The four principles are empowerment, holistic development, family and community, and relationships. The five strands are wellbeing, belonging, contribution, communication, and exploration. Weaving together the principles and strands "give expression to the vision for children." (MOE, 2017, p. 16). This vision is a key statement in the document: children are "competent and confident learners and communicators, healthy in mind, body and spirit, secure in their sense of belonging and in the knowledge that they make a valued contribution to society." (p. 6). Therefore, the principles and strands form the framework within which the local curriculum is built. The curriculum document describes knowledge, skills, and attitudes as combining to form working theories and dispositions. I discuss these notions next.

Working theories and dispositions are both described as a combination of knowledge, skills and attitudes. Therefore, both notions represent a unique perspective of how knowledge, skills and attitudes combine. Dispositions are described as "tendencies to respond to situations in particular ways" (MOE, 2017, p. 22). They are closely related to working theories, having been described as two sides of one coin (Peters, Davis, & McKenzie, 2018). In this research, I acknowledge the close relationship between dispositions and working theories. I also acknowledge that dispositions can lead to the generation and refinement of working theories, and therefore that teaching approaches that focus on children's dispositions can then influence working theory development. However, for the purpose of this research, I have focused on working theories and associated teaching approaches. The influence of dispositions, the associated teaching approaches and the influence that has on working theories could be the subject of further research. I explain the notion of working theories later on in this section, and in detail in chapter 4.

In *Te Whāriki*, the notions of working theories and dispositions provide the basis for 20 learning outcomes and associated goals. In a non-prescriptive curriculum, the idea of learning outcomes might appear ambiguous. However, the learning outcomes are described as "broad statements of valued learning…designed to inform curriculum planning and evaluation and to support the assessment of children's progress." (MOE, 2017, p. 16). The learning outcomes focus on children's developing capabilities, and are preceded by the statement: "Over time and with guidance and encouragement, children become increasingly capable of…" (MOE, 2017, p. 24). Holistic goals are also provided alongside the learning outcomes. The goals are for teachers, and are primarily about pedagogy and setup of environments. For instance, under the

exploration strand, one of the five goals is “They [children] develop working theories for making sense of the natural, social, physical and material worlds” (p. 47). The associated learning outcome is “Making sense of their worlds by generating and refining working theories” (p. 47). Therefore, while there are goals and learning outcomes, they are broad, holistic, and in keeping with the non-prescriptive nature of the document. In addition, I view the three words—increasingly capable of—as meaning that the process of learning is highlighted rather than the content itself. Thus, I view *Te Whāriki* as promoting broad goals and learning outcomes and highlighting a child’s learning journey rather than focusing on prescribed academic outcomes.

It is challenging for teachers to weave the principles and strands of *Te Whāriki* together to create a local curriculum together with children and families (Education Review Office [ERO], 2019; Nuttall, 2005). This challenge places a demand on teachers to understand the curriculum’s philosophical and complex non-prescriptive nature. In addition, teachers need to understand the sociocultural and holistic underpinnings of *Te Whāriki* (Ritchie, 2018). In line with this approach, formative assessment is used to create curriculum as I explain next.

Assessment in New Zealand ECE is carried out informally and formally. In *Te Whāriki*, informal assessment is described as occurring in the moment, while formal assessment occurs through later documentation. A common type of formal assessment occurs through learning stories (Carr & Lee, 2012, 2019; MOE, 2009) written by teachers or adults. In short, learning stories are narrative, credit-based, formative assessments of children’s everyday learning. Both types of assessment are described in *Te Whāriki* as supporting children’s learning and curriculum planning. Assessment is highlighted as being *for learning* (MOE, 2009), and therefore informs curriculum planning, and the weaving of the curriculum whāriki.

The complex and interpretive nature of *Te Whāriki* affords much flexibility and opportunity for teachers. First, *Te Whāriki* is a curriculum framework without prescriptive learning outcomes. Second, teachers are expected to weave a local curriculum with their children, families, and communities. Third, in *Te Whāriki* play-based learning is valued. Thoughtful, informed teachers are therefore required to implement the curriculum in ways which engage with learners and offer engaging teaching and learning opportunities and experiences. Of particular interest to this research, teachers need to be “knowledgeable about children’s learning and development and able to identify their varied abilities, strengths, interests and learning trajectories “, “able to integrate domain knowledge (for example, science and arts

knowledge) into the curriculum" and "knowledgeable about and able to try alternative ways to support and progress children's learning and development" (MOE, 2017, p. 59). This premise offers many opportunities for teachers to try a myriad of teaching approaches. This research investigated teaching approaches that foster working theory development within the context of STEM. I discuss STEM education in ECE next.

STEM education in ECE

This research has been carried out within the context of STEM education meaning that the research design and process has focused on young children's working theories related to the STEM domains. It is important to explore teachers' perceptions of STEM education in ECE to set the scene for the remainder of the research in this study. This section outlines STEM education in terms of this research. A detailed explanation is provided in chapter 3.

ECE settings provide environments with enormous potential for developing early STEM knowledge, skills, and attitudes (Kumtepe &Genc-Kumtepe, 2015). Children in ECE settings likely experience the STEM domains hands-on as they explore nature, design, construct and re-construct with materials and investigate quantity, shape and arrangement. Children's experiences and interactions enable development of early concepts, dispositions and attitudes that have the potential to remain throughout their later schooling and lifetime (Bybee, 2013; Zucker et al., 2016). The New Zealand ECE context, where local curriculum is woven around children's strengths and interests (Lee, Carr, & Soutar, 2013), provides an ideal setting for teachers and children to engage in meaningful STEM teaching and learning opportunities. STEM education is therefore an important and relevant part of ECE in New Zealand.

Because STEM education has been viewed as ill-defined (Bybee, 2013) it is important that I am transparent, and clear about the definition for my research. For this research, I have developed a definition of STEM education as below. I explain this definition in chapter 3.

STEM education represents the knowledge, skills and attitudes about science, technology, engineering and mathematics that are taught and learnt in early childhood settings. STEM education occurs when a combination of two or more of the domains are integrated together in teaching and learning experiences.

The throwing example from the beginning of this chapter provides an example of my definition. While throwing the ball, science concepts such as the physical body might be emphasised, over

technology, engineering and mathematics. Alternatively, when throwing, the emphasis might be on mathematics—for instance measurement of distance and comparison between distances—with the other domains backgrounded. Technology might be the focus, in the form of constructing a tool which aids in moving the ball. Engineering might be a focus as the teachers and children focus on the engineering design needed to make a goal for the ball to hit. These are a small example of many different possibilities.

A common feature of the STEM domains is that they are multi-faceted in terms of process, outcome, and attitudes (Katz, 2010). For this thesis, outcomes can be thought of as knowledge and understandings. Outcomes are intertwined with process which is the development of knowledge, understandings, and skills. As a child is working through the process of developing knowledge, skills and understandings, they simultaneously form outcomes, which can also be thought of as knowledge, skills and understandings. Attitudes are the children's emotions and beliefs about STEM, and about themselves as learners of STEM. These facets of STEM education align with the multiple aspects of working theories which I explain later in this chapter, and in more detail in chapter 4. STEM education can also be viewed as either the individual domains, a combination of domains, or as an integrated whole. In chapter 3 I explain this idea further.

STEM education is therefore a valid and important aspect of ECE. It can potentially develop and shape ongoing skills, understandings, and interests of young children leading to positive individual, community, and economic benefits. STEM both as a whole, and as individual domains, can be viewed as multi-faceted, involving process, outcome, and attitudes, which are consistent with the aspects of working theories, a key part of this research, and which I explain in the following section.

In this research, I investigate teachers' perceptions about STEM education in ECE. A focus on teachers' perceptions about STEM provides an understanding of how ECE teachers view the context of this research, setting the scene for the remainder of the research which focuses on STEM related working theories. This is important as it reduces researcher assumptions that might be made about teaching STEM in the two settings involved in this research. Therefore, research question 1 (and the focus of chapter 3) is: How do teachers perceive the place of STEM education within ECE. I overview working theories next.

Working theories

The notion of working theories is the central focus of this study. Therefore, it is important to examine and explain the notion as it pertains to this research. This section provides an overview of the details, explanations, and arguments that are in chapter 4. Earlier in this chapter, I explained working theories in relation to *Te Whāriki*. I build on this explanation focusing on the perspective of knowledge, skills and attitudes that working theories provide. Next, I theorise working theories as being process, outcome, and interpretive framework, leading to a definition of working theories for this research. I then outline the relationship between working theories and the concepts of thinking, concept development and knowledge building. Finally, I briefly explain the spiral of working theory development model.

In short, and as I describe in detail in chapter 4, working theories are a person's tentative and evolving ideas and understandings about the world. Working theories is a term from the ECE curriculum and is therefore related to young children. However, working theories are not just confined to the younger years—they continue to be generated and refined throughout adulthood (Claxton, 1990). There are two aspects to working theories. First, they are working. This means they can be thought of as dynamic and in progress. Secondly, they are theories. This means they are a best understanding based on past and current experiences and information. However, working theories are more complex than this simple explanation indicates. In *Te Whāriki*, working theories are described as a multi-faceted combination of knowledge, skills and attitudes. Therefore, it is important to explain their place in my research using the perspective of my conceptual framework (explained earlier in this chapter), which I do next.

Knowledge is dynamic and evolving, bound historically, socially and culturally (Wells, 1999). Importantly, for this research, I do not focus on the academic or conceptual accuracy of working theories. Instead, I focus on the broadening or deepening of working theories which might or might not include conceptual accuracy at that present time. Conceptually inaccurate working theories might lead to discrepancies that become clear from later experiences. These discrepancies might then prompt further reflection and critique on existing working theories, leading to further broadening, and perhaps conceptual accuracy. I view knowledge as knowing how, knowing what, and as the product of mental action individually or collectively undertaken from experiences and information. For instance, in the earlier example of ball throwing, information is gained from watching the ball being thrown. That information may be acted on individually or collectively to make sense of the actions seen, leading to the formation of

connections between existing understandings and new information. The ball might then be physically thrown by the individual, providing information from this experience and leading to further knowledge development. The knowledge will now include how to throw the ball, what it means to throw a ball, and how it feels to throw a ball.

Skills are the capabilities to do something (MOE, 2017), perhaps to undertake a physical task or to think about something. For this research, I focus on the mental and physical skills to take information and make sense of it to form working theories. I also acknowledge that other skills such as emotional and social also contribute, however these are outside the scope of this research. Skills are closely linked to knowledge as they can be seen as mental and physical know-how. In the throwing example, skills include the ability to watch others throw balls, to focus on the actions, and the physical skills of throwing the ball.

Attitudes are the children's viewpoints and beliefs (MOE, 2017). Attitudes are closely related to children's beliefs about themselves as learners, their motivation to learn, their confidence to use and develop skills to develop working theories, and for example, their desire to be curious about the world. In the throwing example, the attitudes a child has of themselves as a curious, capable learner seeking to make sense of the world, motivates them to learn to throw a ball.

As I explain in chapter 4, working theories are further multi-faceted, simultaneously being a process, outcome, and interpretive framework. They have been described as both interdependent noun and verb (Davis & Peters, 2011), and are therefore an inseparable and overlapping combination of action and object. This is because as a child goes through the process of developing a working theory, they simultaneously form the working theory. Working theories have also been described as an enhanced interpretive framework (Hedges, 2012) that we pass our new information and experiences through to create further understandings and working theories.

These multiple facets have informed my understanding of working theories for this research. First, I view working theories as a unique perspective of the combination of knowledge, skills and attitudes. Second, they are three-fold, being a process, outcome, and interpretive framework. I draw these elements together below to present my understanding of working theories for this research. My understanding is based on the definition of working theories in *Te Whāriki*. In addition, my understanding draws on the explanations of the various facets already explained in this thesis, and previous definitions and descriptions of working theories (Hedges & Cullen, 2012; Hedges and Jones, 2012; MOE, 1998):

"Working theories are the tentative, evolving ideas and understandings that children develop as they use their existing knowledge…" (MOE, 2017, p. 23) and understandings to make sense of new information. Working theories act as interpretive frameworks of information gained from further experiences and involve skills used to process the new information.

In chapter 4, I critically review prior literature about working theories. I then build on Dewey's (1910) spiral of knowledge model, and Wells' (1999) spiral of knowing model to present the spiral of working theory development model which I have developed throughout this research. This is a unique and innovative model which represents one way to view how young children generate and refine working theories. The model was recursively developed through melding literature, theory, and findings as I explain in chapter 2. I then use the model to frame the findings in chapter 4 to address research question 2: How might young children develop working theories related to the STEM domains?

Working theories is a notion developed in New Zealand which originally drew on Claxton's (1990) concept of mini-theories. As I explain next, research about working theories has been widely published internationally. In addition, working theories have similarities with notions of international significance such as thinking, knowledge building and concept development. Therefore, I argue that working theories hold international significance and research about working theories could provide critical insights and understandings into these notions.

International relevance

Working theories is a notion which hold significant international relevance. Research about working theories has been published internationally. Furthermore, working theories have potential similarities to other related notions. This section overviews the international research, and outlines similarities with such as thinking, concept development and knowledge building.

International publications about working theories are growing albeit, mainly emanating from New Zealand. Prominent New Zealand academics include Hedges (2011, 2012, 2014, 2019), and also include Peters and Davis (2011, 2015). Joint publications between New Zealand based and international academics have also been published (Areljung & Kelly-Ware, 2017; Wood & Hedges, 2016), and working theories research from Switzerland has also been published (Hill, 2015). The notion of working theories is also similar to related notions which I outline next.

First, working theories has similarities with thinking. Given that thinking is a broad notion, difficult to define and that it could be “everything that goes through our heads” (Dewey, 1910, p. 2) it is important to locate thinking in regards to working theories. Working theories have been linked with creative and critical thinking by Peters and Davis (2015) who published a chapter about working theories within a book about thinking and understanding (Robson & Flannery Quin, 2015). The terms thinking and working theories were used interchangeably in their chapter indicating that there is a very close relation between the two. In later work, Peters et al. (2018) noted that working theories develop through complex thinking, again indicating a close relation between the two notions. Similarly, Hedges (2008) noted that working theories provide insight into children’s thinking, and later, that imaginative thinking can lead to working theory formation (Hedges, 2012). Later still, Hedges (2014) noted that working theories might both represent children’s thinking, and be a way for children to connect and extend their thinking. Therefore, for my research, I argue that there is a strong link between thinking and working theories. Working theories are formed through thinking, and represent thinking. But working theories are more than thinking alone. As I argue later in this thesis, working theories are developed through experiences, therefore they have cognitive, physical, and emotional aspects (Hedges, 2019). Nevertheless, strong links remain, and research on working theories could inform understandings about thinking.

Second, working theories also has similarities with concept development. To explain concept development, I draw on Vygotsky’s (1966) work. Vygotsky proposed that concept development occurs in two separate levels: informal, and formal. Informal concepts are contextual, tacit, intuitive understandings developed through interacting with the world. Vygotsky noted three stages of informal concept development: syncretic, complexes, and potential concepts. Formal concepts are non-contextual academic, understandings developed through formal schooling. Vygotsky (1966) argued that together formal and informal concept development gives “body and validity” (p. 109) to understanding. Working theories was linked to this understanding of concepts by Hedges (2012). First, she argued that informal concept development might theoretically underpin working theories. Second, she argued that working theories might mediate the movement between Vygotsky’s three stages of informal concept development. Strong links therefore exist between concepts and working theories. As with thinking and working theories, concept development are similar but not identical.

Third, and finally, working theories have similarities to knowledge building. In short, knowledge building is the development and improvement of conceptual artefacts (Bereiter,

2002) or ideas that are of value to a community (Scardamalia & Bereiter, 2003). Knowledge building occurs through collaborative action and as a responsive attempt to achieve deepened understanding (Wells, 2008). Knowledge building presents another perspective of the components of working theories: knowledge, skills, and attitudes. It is also an element (with experience, information and understanding) of Wells' (1999, 2008) model of the spiral of knowing which I have built on in this research as the spiral of working theory development. I describe this model in chapter 4. Hedges (2014) suggested that working theories could be used as a way to inform understandings about the element of knowledge building. Therefore, again, and as with thinking and concept development, working theories and knowledge building have similarities, but are not identical.

This thesis does not investigate the relationships or influence between working theories, thinking, concept development and knowledge building. I do, however argue that those relationships and influences exist and could be the subject of further research. Suffice for the scope of this thesis, I argue that the potential links and influences mean that working theories are a notion with international relevance.

Just as working theories have international relevance, I argue that teaching approaches which contribute to working theory development must also have international significance. I overview teaching approaches for this research next.

The teacher's role

For this research, I have used the term teaching approaches to describe and explain the role of teachers in fostering and enriching children's working theories. Teaching approaches is consistent with the conceptual framework of this research, representing the flexible, fluid, responsive, and different ways that each teacher might foster and enrich children's working theories. Importantly, my use of the term teaching approaches does not refer to technical strategies that teachers might use. Instead, teaching approaches refers to the underlying theoretical frameworks and broader pedagogical approaches which influence teacher decision making. This section provides a brief overview of teaching approaches which is explained in detail in chapter 5.

The term teaching approaches reflects the contextual, everyday nature of this research, recognises the informal nature of learning in early childhood contexts in New Zealand, and aligns with the sociocultural foundation of *Te Whāriki*. In particular, for this research, I have

positioned teaching approaches as focusing on the sociocultural notion of mediation (Kozulin, 2003; Wertsch, 2007). I specifically highlight the processes and tools used to make meaning as I explain later in this chapter, and in detail in chapter 6. By using a broad lens, and focusing on mediation, I argue that the findings will be more useful for a wider audience than by focusing on strategies that might only be relevant to the participants of this study.

There appears to be a paucity of literature about teaching approaches related to STEM in early childhood. As chapter 5 details, most research carried out on teaching the STEM domains focuses on the more traditional areas of science or mathematics (e.g. Campbell, Jobling, & Howitt, 2015; Linder et al., 2011). However, there is a growing literature base on teaching engineering and technology in ECE, with authors such as van Meeteren & Zan (2010), Bagiati and Evangelou (2015), and English and Moore (2018) writing about engineering, and Mawson (2011, 2013) and Fleer (2016) about technology. The four combined domains of STEM are the subject of little empirical research in ECE although scholars have repeatedly called for its research and dissemination (Dierking & Falk, 2016; Roth & Eijck, 2010). STEM related teaching practices and approaches common across ECE literature include encouraging inquiry (Moomaw, 2013), focusing on real-world contexts (Cunningham & Higgins, 2014), and providing sufficient time (Bagiati & Evangelou, 2015). The importance of teacher mediation in the provision of materials and resources and in dialogue was raised by Moomaw (2013) and Fleer (2009a). Consistent with the findings of this research, Gallas (1995) emphasised the importance of knowing children well. This emphasis is consistent with literature about teaching working theories as I outline next.

Prior research on working theories has identified teaching approaches that are relevant to this research. In their study, Davis and Peters (2011) highlighted that teachers need to deliberately intend to focus on children's working theories, create opportunities and engage with children. Furthermore, they noted that to engage with children and their working theories, teachers needed to know the child well. The importance of knowing children well is a common theme throughout working theories literature. Hedges (2014) found that knowing children well led to the provision of meaningful, relevant experiences. In later work, Hedges and Cooper (2016) found that working theory development can be built on children's interests, again indicating the importance of knowing the children well. Mediation—which I outline later in this chapter, and in chapter 6—was noted as important in the development of working theories by Hargraves (2013). She found that teachers can provide objects and experiences to enhance children's working theories, but that this approach needed to be accompanied with dialogue. In this

regard, Hargraves identified teaching approaches of facilitating, guiding, questioning and suggesting. My earlier research (Lovatt, 2013, 2014) found that mediation underpinned similar teaching approaches to those suggested by Hargraves.

Through the literature review, I found that there is research that identifies specific teaching techniques and strategies that foster working theory development. However, there is little research that investigates and theorises underlying and broader teaching approaches such as those that I sought to investigate in this study. The prior research highlights teaching approaches that focus on knowing the children well, creating and engaging in opportunities and experiences that are authentic and related to children's interests, and engaging in dialogue to mediate children's understandings.

This study aims to add to the research and literature about teaching approaches in ECE related to STEM and working theories. The third question this thesis addresses then is how might teachers foster and enrich young children's working theories about the STEM domains?

To address this question, I draw on the prior research as outlined above, and on the notion of sustained shared teaching (SST), introduced by Siraj-Blatchford, Sylva, Muttock, Gilden, & Bell (2002), and subsequently further developed by Siraj-Blatchford (2007, 2009). I build on the notion of SST, the spiral of working theory development model, and on prior literature related to teaching STEM and fostering working theory development in ECE. I have drawn these aspects together with my findings to develop a model which I call "shared learning commitments" that I explain in chapter 5.

A prominent theoretical construct which I have drawn on to explain and theorise the findings of the research is mediation. I therefore now briefly explain mediation for this research.

Mediation

As I argue in chapter 6, the theoretical construct of mediation is the key theoretical concept that I use to explain the findings of this research. Mediation is situated within sociocultural theory and attributed to Vygotsky, encompassing processes and tools used to make meaning within a cultural system (Kozulin, 2003, Wertsch, 2007). Mediation highlights the influence of material and conceptual tools and artefacts on learning (Daniels, 2015). Wertsch (1991) explained Vygotsky's conceptualisation of mediation as occurring through technical tools such as material objects, and psychological tools such as language and diagrams. Importantly, for

this research, mediational artefacts are two-fold: they are simultaneously conceptual and material (Cole, 1996). Vygotsky (1998) proposed that concepts act as mediators: “To think of some object with the help of a concept means to include the given object in a complex system of mediating connections and relations disclosed in determinations of the concept.” (p. 53). Similarly, Kozulin (2003) noted that psychological tools enable perception and memory when internalised. I build on this thinking in chapter 6 to argue that working theories can be considered as mediators.

The notion of mediation did not become clear as a theoretical explanation until towards the end of data analysis. At times I have been drawn towards cognitive psychology as I have sought to position myself theoretically as I outline in chapter 6. However, cognitive psychology did not provide a theoretical perspective that accounted for the relational and interactive nature of the everyday ECE contexts that I was researching in. As the research, my thinking and understanding have progressed, mediation has clearly stood out as the most consistent theoretical explanation for this research.

Mediation provides theoretical depth to the findings that address the three research questions as I explain in chapter 6. First, teachers’ knowledge, skills and attitudes mediated their involvement in potential STEM related teaching and learning opportunities. Second, I argue that mediation provides a theoretical lens to explain the spiral of working theory development model. Working theories act as mediators of children’s understandings and hence further working theory development. Third, I also argue that mediation provides a theoretical lens to explain the SLC model which is based on the central element of understanding. A mediational lens highlights that understanding children, the concept children are interested in, and understanding the children’s understanding of a concept mediates teaching approaches. In chapter 6, I draw together the findings of the three research questions explained and theorised through the construct of mediation to address the overarching research question: How might working theories about STEM be developed, fostered and enriched in early childhood settings.

Recapping the research questions

To recap, the research questions include an overarching question and three supporting questions.

The overarching question is: How might working theories about STEM be developed, fostered and enriched in early childhood settings?

The supporting research questions are:

1. How do teachers perceive the place of STEM education within early childhood education?
2. How might young children develop working theories related to the STEM domains?
3. How might teachers foster and enrich young children's working theories about the STEM domains?

Addressing each of these three supporting research questions enables me to address the overarching research question as I have explained previously and as I detail in chapter 6.

Summary

This chapter has presented an overview of the thesis including a rationale for the research, my story, my epistemological stance and conceptual framework. I have outlined the context of this research, and explained the key terms. As noted, this is not a typical thesis, as chapters 3, 4, and 5 include separate critical literature reviews, findings and discussion sections respectively addressing each research question. Chapter 6 also has a separate and fuller literature review addressing the theoretical construct of mediation which is then used to theorise the findings and address the overarching research question.

In this chapter, I have presented a rationale for my study, arguing that research on working theories within the contexts of STEM education and ECE is scarce, but critical to inform policy, teaching, learning, and funding. I have explained the conceptual framework guiding this research which brings sociocultural and social constructivist theoretical perspectives together within an interpretivist paradigm. I have explained the two contexts that bound this research: First the New Zealand ECE context, which is guided by the curriculum framework, *Te Whāriki*. Second, the context of STEM which I argue is relevant and appropriate for young children. I also defined the terms working theories and teaching approaches as used for this research. A brief overview of the theoretical construct of mediation as theoretically explaining the findings of this research has been provided. Thus, I have introduced the context and parameters of this thesis.

This chapter has also seen the introduction of the overarching research question which I address in chapter 6, and the three supporting research questions which I address respectively in

chapters 3, 4, and 5. I have briefly outlined two original and innovative models which are crucial parts of this thesis: the spiral of working theory development, and shared learning commitments. In chapters 4 and 5, I argue that these models represent how children developed working theories and how teachers fostered and enriched children's working theories. Before I move on to addressing the research questions, I next explain and justify the methodology and methods used in this research.

2. Methodology and methods

Tē tōia, tē haumatia

Nothing can be achieved without a plan, workforce and way of doing things.
(Mead & Grove, 2001)

As the proverb above says, design and planning is essential for achievement. This chapter describes the design and plan for this research by explaining and justifying the research design and research process. I begin by explaining my use of the terms interpretivist, qualitative and case study. Next, I explain my positioning as researcher, before explaining the methods used to generate and analyse the data. I then describe the process of the model development before finishing with a discussion of the paramount ethical considerations and trustworthiness of the research.

A qualitative methodology (Merriam & Tisdell, 2016) was used for this research, aligning with the conceptual framework of the research. This research is a case study (Yin, 2018) investigating everyday teaching and learning experiences in two ECE contexts. As participant observer, I drew on ethnographic approaches (Hammersley & Atkinson, 2019), spending one morning per week in each of two ECE centres in Auckland, New Zealand for seven months. Data were generated by video recording interactions between teachers and children, by interviewing teachers, and by collecting pedagogical documentation. During and after data generation, I analysed the data using thematic analysis (Braun & Clarke, 2006, 2013), employing a five stage iterative process (Yin, 2015) to provide analytical structure. In addition, for research questions 2 and 3, I used a deductive-inductive-abductive approach (Åsvoll, 2014) based on two evolving models that I developed throughout the research process. The process involved recursively analysing data to refine my understandings and to find consistency between the data and theory.

Methodology

As I have detailed in chapter 1, the conceptual framework for this research brings together sociocultural and social constructivist theories under an interpretivist paradigm. The conceptual framework is interwoven with the methodology for the research. This section explains the methodology using the conceptual framework.

My conceptual framework has guided my methodology, and therefore my research design. The interpretivist, sociocultural and social constructivist components of the framework strongly align with each other. They focus on the influence of society, culture and history, and the construction of knowledge within those influences. The methodology then focuses on making sense of the participants and their interactions within their social, cultural and historical contexts. Through this methodology, I have developed methods enabling me to address the research questions which I discuss later in this chapter.

An interpretivist paradigm

From a methodological perspective, an interpretivist approach focuses on the forming of understandings and subjective meanings about activities, events, experiences and interactions (Merriam & Tisdell, 2016). Interpretivism acknowledges that there are multiple ways to interpret any activity, event, experience or interaction (Creswell, 2014). It necessitates a balance between structured research approaches to address the research questions, and flexibility to enable understanding of the participants perspectives. For this research, an interpretivist paradigm means that I recognise my place as subjective interpreter of the participants, their interactions, and experiences. I acknowledge that alternative perspectives could be used to view the activities, events, experiences and interactions. The interpretivist paradigm influenced my decisions on the methods I chose for generating and analysing data, which I describe later in this chapter. The interpretivist paradigm provided flexibility for me to investigate and address my research questions. I contend that using an interpretivist approach enabled rich data to be generated and in-depth understandings to be formed, and aligned with the theoretical aspects of the conceptual framework which I discuss next.

Research that is influenced by sociocultural theories seeks to investigate relationships between people and their environment, that is their historical, cultural and institutional setting (Wertsch, 1995). Three key aspects of sociocultural research were described by Tracy (2010): First, cognition is culturally mediated by artefacts such as tools and signs. Second, the research is founded in purposive experiences. Third, the research develops historically. My research methodology incorporates a sociocultural approach, consistent with Wertsch's (1995) and Tracy's (2010) views of teaching and learning. I have focused on the interactions between children and teachers, and focused on the interactions children have with the environments which the teachers set up. I have viewed the teachers themselves, and the resources, materials and experiences that they have provided as potential mediating artefacts. Finally, the research

focuses on everyday experiences that took place over six months, meaning that the research incorporates a degree of history in the lives of the participants. As I noted in chapter 1, sociocultural and social constructivist theories are closely aligned, yet subtly different. I briefly explain the methodological influence of the social constructivist approach next.

Methodologically, a social constructivist approach promotes the researcher as actively developing meaning of their data (Maxwell, 2013). The researcher focuses on making sense of the human experience in terms of social, cultural and historical contexts (Kim, 2014). Because social constructivism is an aspect of my conceptual framework, I see my participants as sense-makers of their world (Blaikie, 2004). Through this research, I am attempting to make sense of my participants' interests, experiences and understandings. Therefore, effectively, I am making sense of sense-makers.

I have argued that the methodology of this research has been shaped by the conceptual framework. The methodology is therefore consistent with sociocultural and social constructivist theoretical perspectives, and the interpretivist paradigm. I now move to explain and justify the qualitative nature of this research.

Qualitative research

This research uses a qualitative approach aligning with the conceptual framework of the study. Qualitative research uses interactive methods to understand and reconstruct social realities, to explore, interpret and understand processes and cultural meanings (Braun & Clarke, 2013; Creswell & Creswell, 2018). Qualitative research is a recursive approach, with each stage of the research process influencing the other stages. As such, the research design is then a process of construction and reconstruction (Maxwell, 2013). Data is generated in the form of rich descriptions and explanations (Merriam & Tisdell, 2016). At the same time, analysis is undertaken, focusing on words and meanings (Miles, Huberman, & Saldaña, 2014). For this research, the qualitative approach meant that I sought to form meaning of the children's working theories, and of the interactions between children and teachers that fostered and enriched working theories.

Interpretivist, qualitative approaches have been used in prior research methodologies investigating children's working theories and STEM education. For instance, Haworth et al. (2006) who investigated working theory development in a kindergarten, Davis and Peters (2011) who investigated working theory development in adult-led Playcentres, and Hedges and

Cooper (2014a) who investigated how teachers notice, recognise, and respond to children's working theories in meaningful ways.

Interpretivist, qualitative methodologies align with STEM research principles outlined by Dierking and Falk (2016). They reported on the outcomes of the conference: 2020 Vision: The Next Generation of STEM Learning Research project. A significant outcome from this conference addressed the idea of "life-long, life-wide and life-deep" (p. 1) STEM learners, and in particular a sociocultural research approach to understand the life-long, life-wide and life-deep terms. Five principles important to authentic STEM research that are relevant to my research were developed: framing STEM research within the broad social-cultural contexts; considering STEM learning as a cultural process; viewing STEM education as a lifelong process; investigating STEM content that is worth learning; and examining the engagement of practitioners in STEM learning. Their research principles align with the interpretivist, qualitative methodology and conceptual framework of this research.

This section of the methodology chapter has explained the interpretivist, qualitative methodology used for this research. This methodology provides a means to understand the complexity of the behaviours observed within teacher-child interactions (Bogdan & Biklen, 2007). The methodology aligns with the conceptual framework which I described in chapter 1. In the next section, I explain and justify the use of case study for this research.

A case study

Case study is consistent with, interpretivist, qualitative research, providing a way for researchers to study complex phenomena in-depth within a context (Åsvoll, 2014; Stake, 1995; Yin, 2014, 2018). Case study is an empirical method that investigates the "particularity and complexity" (Stake, 1995, p. xi) of a case in-depth, in a real-world context and with clear boundaries. It follows formal protocols but is simultaneously adaptable and flexible (Yin, 2018) and is therefore suitable for carrying out research of everyday approaches in naturalistic contexts. A case study can be used for both theory-building and theory-testing (Åsvoll, 2014). That premise is critical to this study as the two models which are described in chapters 4 and 5 were developed and refined during the research.

This case study is both explanatory (Yin, 2014) and instrumental (Stake, 1995). First, it is an explanatory case study as I sought to form in-depth understandings, and to theorise how children enrich their working theories. This involved investigating the development of working

theories, and the associated teaching approaches that fostered the development. Second, it is an instrumental case study as I sought to provide insight into working theory development and associated teaching approaches. Therefore, this research aimed to both understand and theorise working theory development and teaching approaches to gain insights and understandings.

Central to case study is the case—or unit of analysis—itself (Stake 1995; Yin, 2018). The unit of analysis is the focus of which is to be studied, providing boundaries in terms of the entire research (Yin, 2018). The unit of analysis then enables decisions about what is to be investigated, and what is not to be investigated (Preissle & Le Compte, 1984). For this research, the unit of analysis is the working theories that young children were developing and enriching during the data generation phase. As I have described earlier, working theories are the tentative and evolving ideas and understandings that children hold. Many theoretical perspectives could be used to view working theory development. My conceptual framework guided my perspective.

The conceptual framework for this research which is explained in chapter 1 provided a particular focus for my unit of analysis. It meant that I focused on the construction of working theories by children within the social, cultural and historical contexts that they were situated in. Although not the unit of analysis, the associated teaching approaches that contributed to working theory development was effectively a secondary focus for my research. Again, the conceptual framework guided my focus. As I have already noted, I viewed teaching approaches as the ways that teachers go about working with children to make sense of the world. They included the direct interactions of the teachers, the experiences the teachers provided, the resources and materials provided, and the environmental setup. In the methods section of this chapter, I describe how I generated data about working theory development and associated teaching approaches.

The unit of analysis then bounded the research, meaning that I focused on the development of working theories. Furthermore, as I explained in chapter 1, this research was carried out within the contexts of the STEM domains in ECE education. Because my research uses an interpretivist paradigm, it is important that I am transparent about my positioning as a researcher as this influences my interpretation. I explain my positioning next.

My positioning as researcher

In chapter 1, I described how I came to be researching young children's working theories and my epistemological stance. In this section, I build on my story and my epistemological stance to explain my beliefs, motivations and underlying assumptions that influence my positioning as a researcher. It is important to make these clear because this research uses an interpretivist paradigm meaning that the research is influenced by my subjectivity, or bias (Maxwell, 2013). This section explains my positioning, first explaining my influences, beliefs and motivations drawn from my ECE teaching background, then from my interest in STEM, and finally my interest in research.

My ECE teaching experience has positioned me in terms of everyday research methods used in this study. My teaching pedagogy was based around warm, deep relationships and empowerment of children, which I brought to this research. My focus on relationships led to the four week introductory period—which I explain in the methods section—which enabled relationships with children, teachers and families to be developed before data generation began. These relationships continued to develop throughout the research process.

Through teaching young children in ECE, I have also come to see the immense creativity, imagination and logic that young children have. The logic might not always be apparent, perhaps due to our wider experiences as adults. In keeping with statements in *Te Whāriki*, I value children as capable, competent and confident learners. This means I take a credit-based perspective on their ideas, understandings and working theories.

My past experience as a teacher-researcher has influenced this research. The research involved collaboration with academics over two years to investigate young children's working theories (Hedges & Cooper, 2014a). This experience helped me to appreciate the difficulties involved in generating data as I was one of the main data generators. I was also involved in focus group meetings which were led by the academics, and which helped shape my focus group design from the questions to ask, to the general approach taken during the interviews. Furthermore, I was also involved in preliminary data analysis and publishing, which aided my thinking during my own data analysis and the writing of this thesis. My involvement meant that I came to my doctoral study with some experience of the complexity of qualitative research in everyday ECE settings.

My positive perceptions towards STEM have been influenced by my background. As a young child I helped my father build the family home. The house building has continued over my lifetime, and I have grown up being involved in many projects around my family's and other homes. Looking back, STEM has been a major aspect in these projects as we planned, gathered the correct types and quantities of materials, built and reviewed. Later, I worked as an electrician, then an electrical engineer where STEM was again prominent. When I moved into ECE teaching, I was drawn towards STEM related teaching and learning with the children. We often developed and engaged with real world problems, working out possible solutions, engaging in construction and evaluating. This background led me to see that STEM education is important for children, and also enabled me to identify STEM related learning while generating data.

Being human, and being involved in qualitative research means data generation and analysis is not a robotic, precisely defined process. Hence researcher bias is of particular concern. In this regard, my background as an ECE teacher could be viewed as problematic. I could easily share the concerns, become a supporter, or friend of the participants. Indeed, at times, teachers did share concerns. For me, that is an integral aspect of the participant observer role. Sharing concerns meant that at times the teachers would share their concerns about the children with me, wondering and reflecting on their teaching approaches and the children themselves. Therefore, at times my position as researcher in the field varied along a spectrum from almost objective observer to fully involved participator consistent with Simons' (2009) thoughts that research can be an emotional role requiring awareness and reflexivity. I view this variable positioning as positive: it deepened relationships leading to deep understandings of the participants and the contexts and therefore to rich data.

Up to this point, I have explained and justified the methodology underpinning this research. I now move on to explain the methods used.

Methods

This section describes the methods that were used in this research. First, I explain the nature of the research as drawing on ethnographic approaches. Next, I explain the settings and participants. I then discuss the data generation methods used which included participant observation through video recording, and field note taking, recording pedagogical documentation, analytic memos, individual interviews and group interviews. Next, I explain

the data analysis which was a recursive process involving a deductive-inductive-abductive (D-I-A) framework (Åsvoll, 2014), thematic analysis (Braun & Clarke, 2006, 2013), and the use of Yin's (2015) five phase cycle. I then discuss the development of the two models—the spiral of working theory development, and the shared learning commitment—created through the research, and the data annotations used.

Drawing on ethnographic approaches

This section first briefly outlines the history and theoretical informants of ethnography, positioning it as flexible and fluid. Next, I explain the key features of an ethnographic study. I then explain how ethnographic approaches have been used in this research. I finish by arguing that my study cannot claim to be ethnographic, however, it draws on ethnographic approaches and therefore provides the richness and depth that ethnography offers.

Ethnographic research is consistent with interpretivist, qualitative research (Creswell & Creswell, 2018). Ethnography leads to an interpretation and understanding of the culture being studied (Creswell, 2013). Researchers seek to "get inside the way each group of people sees the world" (Crotty, 1998, p. 76) to understand their perspectives and practices. Thus, ethnographic approaches focus on culture, consistent with the sociocultural aspect of the conceptual framework of this research. Ethnography can lead to rich and descriptive data about the activities of the participants, their beliefs, the context, and insights into theory and practice (Eder & Corsaro, 1999; Preissle & Le Compte, 1984). However, ethnography has varied and contested meanings throughout the literature (Hammersley & Atkinson, 2019). Therefore, it is important to explain ethnography in relation to this research.

Ethnography has a complex history based on anthropology (Creswell, 2013). Since the original understandings, ethnography has developed to include sociological, psychological and cultural influences (Hammersley & Atkinson, 2019). The term ethnography therefore is a cultural and historical construct and is dynamic and fluid. Understandings of ethnography have changed over time and will likely continue to change over time.

Five key features of ethnography have been raised by Hammersley and Atkinson (2019). First, everyday actions and accounts are studied. Second, data is generated from multiple sources, but predominantly participant observation and informal conversation. Third, data generation is relatively unstructured. Fourth, the research is in-depth and small-scale. Fifth, data analysis

focuses on meaning and consequence. These five features are consistent with this research as I explain next.

The five key features of ethnography have been incorporated in my study as follows. First, this research focused on naturalistic settings and everyday teaching and learning. Second, participant observation—as I explain later in this chapter—was the main method of generating data. Informal conversations with the participants also took place and were recorded in my field notes. Third, data generation was guided by my initial expectations regarding where I thought STEM related teaching and learning experiences would occur. However, I soon found that I needed to be flexible and open to alternatives, and the data generation became unstructured in so far as listening for and observing potential opportunities. Fifth, the analysis focused on making meaning of the children's developing working theories and the consequences of the teacher and children interactions and experiences. In this regard, I argue that the research could be considered ethnographic. However, as I explain below, I cannot make the claim fully, and instead argue that I have drawn on ethnographic approaches.

My research drew on ethnographic approaches. I aimed to form understandings and make meanings by actively entering the worlds of those that I was researching (Denzin & Lincoln, 2002). In keeping with ethnographic approaches, I have noted the everyday nature of the research throughout this thesis. The word everyday refers to data generation being based on the normal events, activities, or experiences that would occur on any day in either of the two ECE centres. However, I cannot claim that this research was ethnographic. This is because literature states that ethnography involves extended, considerable, or prolonged time in the field, and in the daily lives of the participants (Creswell, 2013; Hammersley & Atkinson, 2019). The nature of this time is not defined and is perhaps undefinable. As I describe in detail later in this chapter, I view my data generation period as being prolonged, attending both ECE centres for six months, plus a one-month familiarisation period. However, I was not part of the prolonged daily lives of the participants as I attended the ECE centres for only one morning per week.

Nevertheless, I do claim that much of the research process was consistent with ethnographic approaches. Furthermore, ethnographic approaches meant that I focused on the complexity involved in working theory development, generating rich and deep data based on relationships and knowledge of the settings. Therefore, by drawing on ethnographic approaches, I formed

deep insights and rich understandings of the contexts and participants. I describe these contexts next.

The participants and settings

This research was undertaken at two ECE centres in Auckland, New Zealand. The first setting was Charleston Early Childhood Education Centre (pseudonym, hereafter referred to as "Charleston"), which had three qualified and registered teachers, and was licensed for 40 children to attend aged between 2 and 5-years-old. Up to 30 children attended on any day from 8:45am-2:45pm. Two of the teachers at Charleston left towards the end of the data generation period. This research uses the data generated with these teachers up till the time they left. Because these teachers were replaced by temporary staff, with whom I had not established relationships, I chose not to include the replacement teachers in this study. The second setting, Piccadilly Early Childhood Education Centre (pseudonym, hereafter referred to as "Piccadilly") had eight teachers, three of whom were qualified and registered. Piccadilly was licensed for 45 children to attend, including up to 15 children aged under two. Up to 30 children attended this centre daily between 7:30am and 5:30pm. Some children at both centres turned five over the data generation period and left the centres to attend school. Data generated with these children up till the time they left was retained and used in analysis. At the same time, new children enrolled and became new participants. Both centres were mixed age, meaning that there were no separate rooms or areas for younger children with one exception. At Piccadilly, there was a small area that was reserved for infants. The use of this area was flexible, depending on the numbers of infants and the activities and experiences that they were engaged in. At the teachers' discretion, older children could come into this area.

The participants included the children and teachers at both centres, and me as participant observer. The primary child participants were 3 and 4-year-old children, mainly because they are verbal and able to express their working theories in ways which I can understand more readily than pre-verbal children. However, younger children attending the centres were also included as participants for two reasons: First, to acknowledge the sociocultural framing of the research, and therefore the social and cultural influence that all children have on their peers' learning. Second, because of the nature of one of the data generation methods—video recording—specifically the possibility that younger children might also move into the video being recorded. If these children were not participants, then I would need to stop the recording.

The two ECE centres typified free-choice, play-based teaching and learning environments where children engaged in experiences of their own choosing. Both centres had indoor and outdoor areas which the children could freely choose to move between. The indoor area at Charleston was one large, open space with areas such as family play where equipment such as a pretend refrigerator, stove, beds, and dress-up materials were available. Charleston also had an indoor construction area for building with wooden blocks, a small library with children's picture books, spaces for art, and a table that was dedicated to playdough. The indoor area also had a space for the children to sit together on a large mat. The outdoor area at Charleston included empty grassed spaces, where the teachers set up different materials and resources each day, a garden, three permanent swings, a large sandpit, and a large playground. The indoor area at Piccadilly was slightly different as the building had previously been a house, reconfigured into an ECE centre. Similar to Charleston, Piccadilly had library, playdough, family play and art areas. It also had one room that was mainly used for construction with wooden blocks. As noted earlier, Piccadilly had one space that was generally reserved for infants. Again, similar to Charleston, Piccadilly's outdoor space included a sandpit, garden and swings. The outdoor space also included a semi-permanent climbing frame, a slide, and a small hill. At both centres, the use of the areas was flexible and fluid, and children often brought materials, resources and their learning experiences from one area to another.

At Charleston, most children would arrive between 8:30 and 9:00am. Generally, the teachers arranged equipment, resources and materials prior to the children's arrival. Children then engaged in self-chosen activities and experiences until approximately 10:00am when all the children and teachers gathered together, and sat on the aforementioned mat. One teacher would lead this time, where children and teachers would sing, dance, read books, and engage in discussions. Other teachers sat with the children to assist the leading teacher. The children would then go immediately to morning tea, where all children and teachers sat at tables together eating and drinking. Typically, morning tea would end at approximately 10:50am, after which the children again engaged in self-chosen activities and experiences. At approximately 12:30pm, the children then had lunch together at the same tables with the teachers. The teachers had daily roles defined by areas of responsibility. One teacher was responsible for the outside area, one for the inside area, and the third teacher was available for both areas. The roles had a degree of flexibility, and the teachers could swap areas throughout the morning if required.

At Piccadilly, most children would arrive between 7:30 and 9:00am. A teacher explained that "there is no structure to the [Piccadilly] day" (FN, 29.03.17)—please refer to the end of this

section for data annotations. This was true, however in my field notes I wrote my thoughts “but actually there is. It’s the children’s rhythm, not imposed upon by the teachers” (FN, 29.03.17). By this, I meant that as children arrived, they often engaged in quiet inside experiences such as art, and block play. By approximately 9:30am, many children would appear ready to go outside, and teachers would then move outside with them. There was no official mat-time, however sometimes the children would initiate a small group time where they would ask a teacher to read books to them. There was no official morning tea, however between 10:00 and 11:00am, many children would come together for short periods to eat a morning snack, accompanied and sometimes reminded by a teacher. The one interruption to the day was for lunch at about 12:30pm where children and teachers gathered to eat together. Teachers were not assigned roles according to areas of responsibility. However, as there were infants and toddlers attending, three teachers were specifically responsible for these young children.

This section has described the participants and the settings for the research. I now move on to explain the data generation and then the data analysis methods used.

Data generation

In this section, I explain and justify the data generation techniques used. I begin with an explanation of the alignment with the conceptual framework, a description of the familiarisation period, then an explanation of how data were generated.

The data generation process was consistent with the conceptual framework—which I explained in chapter 1—and the methodology—which I explained earlier in this chapter—of this research. Being interpretivist research, it was important that I spent a prolonged time gathering data to deepen relationships, to enrich my understandings of the participants and settings. This deepening of relationships and understandings would then enhance the trustworthiness of the research. As already noted, I therefore spent one morning per week in each centre for one month immediately before data generation. I discuss this one month period next.

The familiarisation period.

The decision to have an extended familiarisation period was based on the interpretivist, everyday nature of this research. A familiarisation period would enable me to develop relationships with the teachers, children and their families, reduce the novelty of having another adult—and especially in my case, a male adult— in the centres, and reduce the novelty of my data generation methods. I provided a letter introducing myself and my research for each family

(see Appendix A). Both centres introduced me to the children's families in their newsletters, and the Charleston teachers placed my photograph and some information about my background and research on their daily display board. During this familiarisation period, two moments stand out. First, at Piccadilly, my wristwatch featured prominently with some children, particularly Frank who is referred to in chapter 4. As I sat with the children and talked with them, Frank would often show an interest in my wristwatch, comparing it with his father's. He would often ask if he could wear my watch, which I would give to him, at first with a little trepidation. However, Frank took care of it and would always return it later. This small episode was vital for building trust with the children and developing strong relationships. It showed Frank that I trusted him, gave him an opportunity to engage and share with me, and showed the other children that I was trusting, and perhaps trustworthy. In addition, as one teacher noted, the children were all talking to their parents about me (FN, 27.03.17), and I expect that Frank shared with his parents about the wristwatch, which also likely aided the development of warm professional relationships with his mother and father. Second, at Charleston, during the familiarisation period, I would often have my field notes journal with me. The children were interested in this and we discussed what I would write in it. Some of the children asked if they could write in it too, and as with my wristwatch, I passed my book over to them. The children drew pictures, an excerpt of which I show below as Figure 1.

Again, I found that sharing an object that was personal and meaningful to me demonstrated trust in the children and aided the development of strong relationships. I think that the warm relationships which I was developing with the children also positively influenced the teachers' views of me and my research.

The familiarisation period was not a time of data generation, however it provided information that helped with later data generation. This time helped me to understand the routines of the centres, the children's interests and capabilities, and to develop initial understandings, or hunches, of how I could physically position myself, and where I was likely to generate data that would address my research questions. After a month I felt that I was well prepared for data generation.

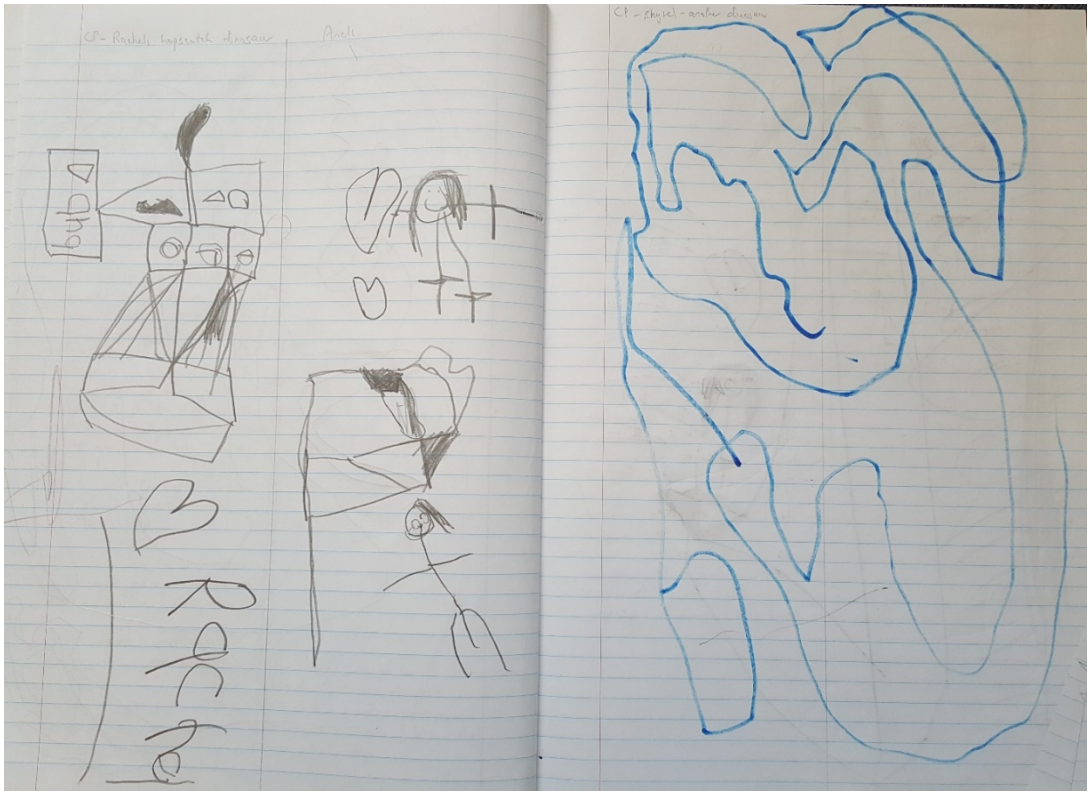


Figure 1. An example of how children used my field note journal.

Data generation involved two distinct phases. First, recording selected video footage, writing field notes, and taking photographs of pedagogical documentation. Second, facilitating and recording individual teacher and focus group interviews. The next sections discuss these two phases.

Participant observations.

Data generation needed to be flexible and adaptive due to the everyday nature of this research. In general, I would attend each centre between 8:00am and 12:30pm. Normally, I would begin with an informal chat with the teachers about the previous week's visit, anything that had continued while I was away, and any current strong interests/themes or events happening that day. As children engaged in experiences and activities, I would observe carefully, listen and watch the children and teachers before choosing to generate data. This decision was a challenge as I explain next.

The everyday ECE contexts meant that it was difficult to decide when to generate data. Furthermore, the flexible and adaptive ECE contexts meant that there was no guarantee that teachers and children would engage in STEM related teaching and learning while I was there. Preissle and LeCompte's (1984) ideas helped me address this challenge. They suggested that

theoretical, conceptual frameworks, intuitive reactions and hunches can be drawn on as a guide. In keeping with their thoughts, I looked for the following: instances where children and teachers were engaged together; instances that seemed to have a component related to the STEM domains; instances where children seemed to be developing and enriching working theories; and instances where I could see a continuity from previous data generation. In addition, early data analysis also guided me to look for recurrences of the early patterns and themes that I was identifying.

Participant observation has been the primary data generation method for this research. Participant observation is a method consistent with qualitative, ethnographic approaches (Creswell, 2014). A participant observer actively participates in what is being studied, enabling the researcher to "truly learn about a situation" (Creswell & Guetterman, 2019, p. 214). Being an interpretivist study, it was important for me to truly learn about the context and participants to enable deep, rich understandings and insights, and hence enhanced trustworthiness of the findings. While at each centre, I observed closely, and listened carefully to the interactions that were taking place, seeking to generate data that would help me to understand and interpret the thinking and understandings of the teachers and children. I describe my participant observation methods next.

I used video recording to generate the majority of my data while engaging in participant observation. Video data enables multiple re-views of an experience, with the potential to observe aspects that were not noticed during data generation (Cherrington & Loveridge, 2014). Such aspects include dialogue, facial expressions, body language and actions (Robson, 2011). The subtleties and details that video might highlight, and which might not be observed in the moment, can then lead to rich interpretations, and reduce misinterpretation (Walsh, Bakir, Lee, Chung, & Chung, 2007). I used a mobile phone for video recording. I introduced the device during the familiarisation period both to test its effectiveness, and to reduce the novelty for when data generation began. The episodes that I video recorded varied in length from under a minute to up to an hour. To make the video data files manageable, I generally stopped and immediately restarted the video recording every two minutes meaning that there were often multiple, consecutive files for one episode.

Generating data by videoing teachers and young children is potentially intrusive and ethically problematic (Cutter-McKenzie, Edwards, & Widdop Quinton, 2015). I approached the video recording respectfully, mindful of being in a privileged position that allowed access to the

centre and the teachers' and children's everyday lives. The teachers and children were fully aware that they could ask for the recording to stop at any time. Furthermore, I remained cognisant of children's and teachers' body language and non-verbal communication and stopped recording data if needed. I chose to use a mobile phone to record video. This decision was based on my previous research experience (Hedges & Cooper, 2014a) where I had used a video camera. The video camera resulted in children often "acting" when noticing that they were being recorded. I expected that using a mobile phone would reduce the novelty of the recording device as it was a device that many children are very familiar with. Coupled with introducing the mobile phone during the familiarisation period, I found this device did not intrude or result in acting by the children. Teachers were also more comfortable with the mobile phone than with a video camera, as they sometimes used their own phones to record children's learning experiences. A second way of recording data from participant observations was through writing field notes which I describe next.

I used a mixture of descriptive and reflective field notes (Creswell & Guetterman, 2019). Descriptive field notes described the events and experiences, while reflective field notes recorded my thoughts on those events and experiences. For transparency, to seek feedback, and to continue to build strong relationships with the teachers, I emailed both centres a copy of my descriptive field notes each week. I found that doing so deepened my relationships with the teachers as they saw evidence that I was recording data to inform my research and not to make judgements on their teaching abilities.

Building on the notion of reflective field notes, I wrote analytic memos (Creswell & Guetterman, 2019) to document my ongoing thinking during data generation and throughout the entire research process. Analytic memos are consistent with ethnographic approaches, being reflective, written notes about strategies and emerging ideas (Hammersley & Atkinson, 2019). The memos had an important role in the process of data generation as I reflected on my role as participant observer, my research questions, and ethical challenges. As I expected, the day to day nature of data generation was not a structured, foreseeable process. Writing memos provided a way for me to structure my thinking, build logic and reflect on the data generation process and on the data analysis process which I detail later in this chapter.

Interviews and focus groups.

Interviews are an important data source in case studies (Yin, 2018). They offer flexibility, allowing the researcher to pursue emerging events and to uncover feelings and thinking that

cannot be observed (Simons, 2009). I used individual and focus group interviews to generate data about teachers' beliefs, understandings and insights. This research used a semi-structured approach (Brinkman, 2018) for both individual teacher interviews, and focus group interviews. Semi-structured interviews provided leeway for me to be flexible and to follow up on aspects I deemed important. In addition, I used open-ended, indicative questions during interviews, consistent with qualitative, ethnographic research (Creswell, 2014). Prior to the interviews, I developed the questions, aware that because of the semi-structured nature of the interviews, they would be indicative only, and would therefore act as a guide. Examples of the questions are included in Appendices E and F. The interviews therefore brought a mixture of pre-planning about the data I hoped to generate, and an open-mindedness to adapt to the unexpected. The interviews were audio-recorded, transcribed by me, and provided to the participants for editing. Next, I explain the focus group and individual interviews.

Focus groups interviews present an opportunity for the researcher to gain multiple perspectives from a group of participants, and for the participants to reflect on the thoughts of others, resulting in further data (Braun & Clarke, 2013). The focus group interviews were semi-structured, promoting dialogic conversation (Kamberelis, Dimitradis, & Welker, 2018) between the interviewer (myself) and the participants, and between the participants themselves. In this way, my role was effectively as moderator of a guided discussion, promoting interaction between the participants (Braun & Clarke, 2013). The focus groups took up to 1 ½ hours each. Each focus group interview involved the teachers of that centre only. At Piccadilly and Charleston, the first focus group interviews took place shortly after the end of the familiarisation period. The purpose was to gather data about teachers' initial thoughts about the place of STEM education in ECE, to gather data about teachers' understandings about working theories, and to discuss any queries about the project. At Piccadilly, six teachers took part, and at Charleston, all three teachers took part. Towards the end of data generation, a second focus group interview was planned. This did not occur at Charleston as two teachers left the centre before the end of the data generation period. At Piccadilly, the second focus group interview took place with five available teachers. This interview took approximately 1 ½ hours covering teachers' ongoing thoughts about the place of STEM education in ECE and their views of working theories. In keeping with Cherrington and Loveridge's (2014) thoughts about using video stimulated recall to prompt teacher reflection, this focus group interview involved showing a short video from the data generated at their centre. We then discussed the video in terms of the children's working theories and the teachers' approaches. The focus group

interviews were dynamic times where conversations ebbed and flowed. The interviews reflected the thoughts of Ryan and Lobman (2007) and Cohen, Manion and Morrison (2013) about the benefits of focus group interviews where teachers question each other and build on each other's thinking as they reflected on their own thinking and practice.

Towards the end of the data generation period, and guided by indicative, open-ended questions, I undertook interviews with individual teachers to gain data about the teachers' insights into their teaching approaches, their intentions and their understandings of the children's developing working theories. At Piccadilly, the teacher interviews took place during one day in an office at the Piccadilly centre. Through the research, funding was made available for the centre to employ an additional teacher to accommodate the need for one teacher at a time to be interviewed. At Charleston, the three teacher interviews took place after children had left the centre for the day, on three different days. For both centres, the interviews lasted for up to an hour, using the indicative, open-ended questions (see Appendix F) and included viewing a short video excerpt. Consistent with Cherrington and Loveridge's (2014) thoughts about the power of video stimulated recall, and as occurred in the second focus group interview detailed earlier, I showed a video excerpt of one example of the teacher in each interview interacting with children. After viewing the video, we then discussed the teacher's thinking, motivations, and expectations at the time and their reflections on the experience after re-viewing it. This process provided deep and rich understandings of the experiences both for me and for the teachers.

Pedagogical documentation.

Documentation is a valuable data source in qualitative studies (Creswell & Guetterman, 2019). Because documentation is often the result of careful and considered thinking, it may offer deep insights into the participants thinking and intentions, corroborating, contradicting and informing other types of data (Yin, 2018). Documentation was therefore an important part of data generation for this research. Documentation included individual children's learning stories (Carr & Lee, 2012, 2019) associated with STEM and/or working theories, and wall displays relating to teaching and learning about STEM and/or working theories. Because neither working theories nor the STEM domains were explicitly mentioned in this documentation, I looked for other key words such as thinking, understanding or ideas. I also focused on themes, for instance looking for documentation about STEM related teaching and learning such as construction, nature and transport. Figure 2 shows a learning story from Charleston which does not mention working theories or the STEM domains. However, the story is about problem

solving by engineering and building a design based on the nature of animals requirements, using geometric skills to align and build animal enclosures. This learning story illustrates that documentation alluded to STEM related working theories, but did not refer specifically to it.

Figure 2. A learning story about animals and enclosures (CD/2017).

Further documentation included philosophy statements for each centre, teacher information sheets, and centre goals and aims, which were photographed and transcribed. This documentation was generally about wider areas of teaching and learning than working theories and the STEM domains. However, this documentation added a further layer of understanding and insight into the thinking, motivation and expectations of the teachers, and was therefore considered an integral part of the data.

Documentation about planning, and minutes of meetings related to teaching and learning about STEM or working theories was also recorded and transcribed. Similar to the issues with learning stories and wall documentation, often this documentation did not explicitly mention working theories or the STEM domains. Again, I looked for terms such as children's thinking, ideas and understandings, and themes such as construction, transport and areas related to science and mathematics.

A particular strength of my approach was that the extended time spent in each centre meant that I never felt pressured to generate data. This gave me time to develop relationships and learn about the participants, and generate data that I felt would address the research questions. The result of generating data for one morning a week in each centre for six months resulted in much data available for analysis. A total of 504 photos and approximately 21 hours of video was generated as well as field notes and interviews.

Acknowledging the nature of case study, analysis occurred both during and after data generation (Yin, 2018). The methods used to analyse the data are the subject of the next section.

Data analysis

This section explains the data analysis for this research. I begin by outlining how I analysed the data to address each research question, explaining the differences between addressing research question 1 in comparison to addressing questions 2 and 3.

Data analysis was an iterative and recursive process beginning when data generation was being undertaken. The research questions and the conceptual framework of the research guided the analysis. I used thematic analysis (Braun & Clarke, 2006, 2013) to search for and to identify patterns in the data. The five stage process of compile, disassemble, reassemble, interpret and conclude (Yin, 2015) provided an iterative, recursive structure to the thematic analysis. However, data analysis was undertaken differently for research question 1 as it was for research questions 2 and 3. The next section details these differences.

The first research question was how do teachers perceive the place of STEM education within early childhood education? To address this question, my data analysis involved thematic analysis and Yin's (2015) five stage process.

The second research question was how might young children develop working theories related to the STEM domains? As I describe in the next section, I had developed an early version of the spiral of working theories development model during the research design and literature review stages which I thought might address this question. However, for the first iteration of data analysis, I ignored this model, using thematic analysis, and the five stage process to search for prevalent patterns or themes which might provide an alternative explanation to the research question. I did not find an alternative, and therefore proceeded with a second iteration of thematic analysis using the four elements of the model as a basis for pattern and theme identification. As I describe further on in this chapter, the process then involved deduction, induction and abduction (Åsvoll, 2014) as the model guided the analysis, but was then modified by the findings from the analysis. This was a recursive process, carried out until the data and model (and later the theory as I explain in chapter 6) were consistent.

The third research question was how might teachers foster and enrich young children's working theories about the STEM domains? Similar to question 2, I had developed an early version of the shared learning commitment model during the research design and literature review stages which I thought might address this question. In this case, the model was at a much more preliminary stage. Because of the preliminary nature of the model, and because the results of the first iteration for research question 1 had shown that the model (albeit in a revised form) was likely the best for the data, I chose not to do general thematic analysis (Braun & Clarke, 2006, 2013) for research question 3. Instead, I used the preliminary model as a base for pattern and theme identification. Major refinements occurred to this model as I describe later in this section, requiring further thematic analysis. The thematic data analysis for research question 3 then also involved deduction, induction and abduction. The next sections describe the processes used for data analysis.

Informal analysis.

During each day's data generation, I did a preliminary analysis, or informal analysis (Yin, 2018) of my data. This was a non-structured time, sometimes during my time at each centre and often immediately after the centre visit where I would reflect on the data generated, make notes, and make early decisions about whether to retain the data or delete it. For instance, after

video recording an experience that did not appear to be related to STEM or working theories, I would move to the centre office, reflect and make a quick decision about whether to retain the data. My decision normally centred around whether the experience was a continuation of past experiences, the participants involved, and the video length—generally, the longer the video the more likely I was to retain it as I expected that STEM and working theories might be evident on review. At times, I also moved to the centre's office to reflect on the experience, and write further field notes. Immediately after leaving the centre, I would sit in my car, and read my field notes, adding detail if required, and reflecting on the experiences. Next, it was time to compile my data.

Compilation.

Data analysis began shortly after data generation commenced, beginning with the phase of compiling. This phase involves the formal arrangement of the data into a database (Yin, 2015). Annotations for the data were developed which I describe later in this chapter, pseudonyms for the participants were assigned, and a file naming structure was developed. Immediately after each morning visit was finished, I uploaded video data and photographs onto a computer, named the files and then viewed them. I used a spreadsheet which accomplished two functions: First, to manage the data, second, to record my initial thoughts about the content, the participants involved, and which research question the data addressed, consistent with the idea of jottings (Miles et al., 2014). The headings of the spreadsheet are included below as Figure 3.

File name	Date	Description	Research Question	Thoughts

Figure 3. Initial compilation database headings.

Manipulation of the spreadsheet allowed me to organise my data by common topics and themes, the participants involved, and which research questions were being addressed. This organisation then guided my further data generation by indicating themes, topics, and participants who were regularly involved in STEM/working theory related experiences. The ongoing analysis therefore informed the data generation as is common in qualitative case studies (Yin, 2018). I continued to use the spreadsheet throughout the data generation period before using further software which I describe later in this section.

It quickly became apparent that the large amount of video data being generated would be unmanageable for transcription and full analysis. I then re-viewed all data and made a second spreadsheet, summarising each data. I used both the initial and summary spreadsheet as filtering tools. Filtering enabled me to identify the adequacy of the data and therefore to make decisions about which data should be fully analysed as I describe next.

File name	Date	Description	Why recorded	Tags-Children	Tags-Teachers	
Tags-Interest	Tags-Activity	Tags-Other	Tags-WTs	Tags-WT formation	Research Question	Notes

Figure 4. Compilation summary database headings.

Ethnographic data analysis involves continuous decision making about which data to retain and omit (Miles et al., 2014). Decisions about which data to keep for full analysis were difficult and recursive. Primary factors included first, whether the data addressed the research questions. For instance, identifying that the data was STEM and working theory related, and teacher interactions were evident. Second, if similar evidence was provided from multiple sources. For instance, if there was documentation or data from interviews about the experiences recorded. Third, if the theme and/or participants were related to prior/subsequent and ongoing data. The decision making was a recursive process as deeper analysis sometimes revealed themes that linked to previously omitted data which was then reintroduced.

Memoing.

Memoing played an important role in data analysis. It enabled me to reflect on the analysis, and question my decision making and logic. Memoing varied from descriptive writing detailing the process to reflective writing, looking back at what I had done, but also looking forward to tentatively wonder where the data analysis as it currently was, might head.

Data analysis software.

As the decision making was taking place, I used the computer software package QSR NVivo as an analytical tool. NVivo was used to firstly provide a means of managing the individual data files reflecting a continuation of the compiling phase (Yin, 2015), and secondly as an analysis tool—which I describe later in this chapter. I transcribed video and audio data, and described or transcribed photos where they included text, and inserted the transcriptions and

descriptions into NVivo as data sources. Field notes were also inserted as data sources. The early decision making, and compiling phase overlapped, and had many iterations as transcribing data sometimes highlighted that it was not adequate, and at other times transcription highlighted previously unseen links to omitted data which was then re-introduced. Next, I categorised the data into the research question(s) that it addressed as I decided to code the data three times, once for each research question.

The next phases: disassembling, reassembling, interpreting and concluding (Yin, 2015) involved multiple iterations of coding, searching for and identifying patterns and themes using thematic analysis. In particular, this stage involved searching for themes; reviewing themes; defining and naming themes; writing and final analysis (Braun & Clarke, 2006, 2013).

I used NVivo as an analytic tool for coding the data. The software provided a way to disassemble the data through examination and coding to identify patterns. It also provided a way to reassemble the data by interrogating both the data and the coding for common themes. Effectively, I deconstructed the data into codes, then reconstructed the data into themes. The process began with using the initial coding descriptions from the preliminary spreadsheet (interest, activity, children, teachers, working theories involved, ways that working theories were developed), and evolved into new themes as analysis progressed. These phases were different for each research question as I explain next.

Data analysis relating to research question 1.

To address research question one, based on hunches developed through data generation and initial analysis, I first approached analysis expecting that a model could be created showing a hierarchy of events, expectations and experiences that enabled teachers and children to engage in STEM teaching and learning. However, the further analysis stages of disassembling, and reassembling quickly showed that this was not the case. I then conducted further thematic analysis, the results of which are described in chapter 3.

Data analysis relating to research questions 2 and 3.

For research questions 2 and 3, I used a deductive-inductive-abductive (D-I-A) approach (Åsvoll, 2014). The deductive stage involved the development of two tentative models respectively addressing research questions 2 and 3. Initial versions of these models were developed during the research design, and in particular the literature review stage. The

inductive stage involved the analysis of empirical data. In regards to research question 2, I coded the data to headings as per Figure 5.

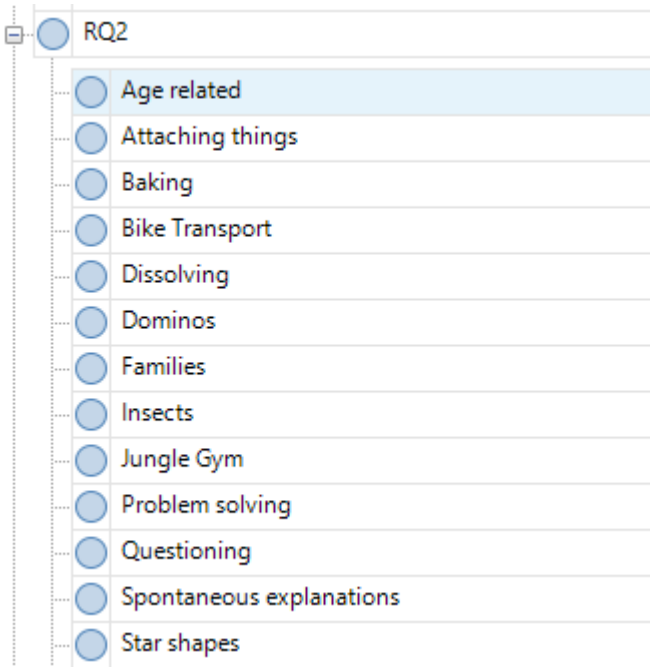


Figure 5. NVivo headings for research question 2.

These headings were common themes that children were developing working theories about. Within the headings, I then searched for the ways that the working theories were being developed. Prevalent alternatives to the model were not identified, however, the open analysis indicated that the spiral of working theory development model might be representative of the data. Therefore, I coded each heading consistent with the elements of the spiral of working theories development model.

In regards to research question 3, the shared learning commitment (SLC) model was at a preliminary stage. I attempted to code the data to the preliminary elements of the model but found that these elements were not representative of the data. Multiple iterations were required between coding and model refinement. Figure 6 shows the headings I used during the iterations.

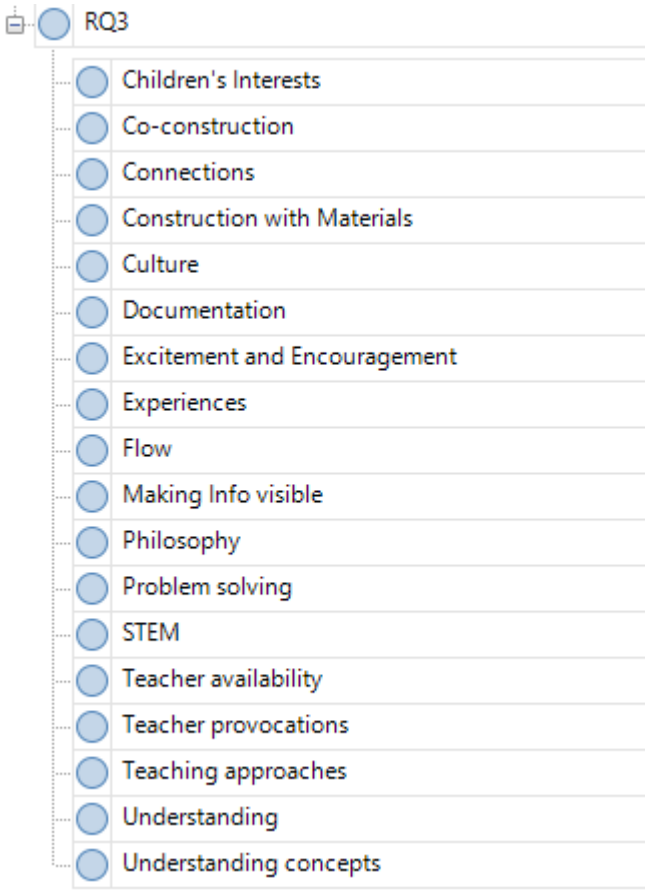


Figure 6. NVivo headings for research question 3.

As the analysis progressed, both models were substantially modified. Therefore, the models were developed through deductive techniques, informed and modified through induction, and refined using abduction to a point where theory and data are consistent. The next section describes this process in more detail.

Development of the models

The two models which I have created and refined throughout the research have acted as dynamic frameworks for this study. First, the spiral of working theory development model (see chapter 4). Second, the shared learning commitment (SLC) model (see chapter 5). Both models are predicated on the notion that experiences provide information, and that information can be linked to existing understandings to form new understandings. Methodologically, this thinking aligns with an interpretivist stance, where people make varied and multiple subjective meanings of experiences.

The initial idea for the spiral of working theory development model was sparked during my Master of Professional Studies research (Lovatt, 2013) while reading Bruner's (1977) work

about spiral curriculum. During the literature review stage of this present study, I built on Wells' (1999, 2000, 2002, 2008) work on the spiral of knowing and Dewey's (1910) work on the spiral of knowledge, to develop a model focused on working theory development. The first full iteration of my model included Well's (1999) elements: understanding, experience, information and knowledge building (which I now call making connections). During data analysis, I used the model as a framework to analyse how children might develop their working theories, and found that three elements (experiences, information and understanding) were consistent with the data, but that the knowledge building element was not. This prompted reflection on whether my entire model was suitable. However, after further analysis, reading and reflection, I found that the spiral model was both a representation of the findings and a framework for analysis of the data if two changes were made: First, by changing knowledge building to making connections. Knowledge building referred to a more prolonged period where children worked together to build their knowledge based on much information, and one iteration of the spiral could represent one class lesson. Whereas, making connections represents the dynamic connections made by the children between their existing understandings and the new information gained from the experience. Second, that the model represented multiple instances where new information was gained, connections were made, and new understandings formed. Multiple iterations would likely occur during any experience as new information was constantly gained and connections made. For instance, at a water trough, a child might spend a prolonged time pouring water between two containers. Each time they poured, it is likely that new information was gained, new connections made, new understandings and working theories formed. The final version of the model is represented in chapter 4.

The SLC model has had multiple iterations throughout the research. The first iteration was developed prior to data analysis drawing on the notions of sustained shared thinking (Siraj-Blatchford et al., 2002) and joint involvement episodes (Bruner, 1996). The first iteration included four distinct areas: trialogy (Paavola, Engeström, & Hakkarainen, 2012), knowledge building, working theories and the spiral of working theory development elements. This initial model was quickly found to not be a true representation of the data, and the elements were changed to dialogy (Wells, 2008), making connections, working theories and the spiral of working theory elements. Again, the model did not provide a representation of the data, and it was modified to include the four elements of the spiral of working theory development, but from a teaching perspective. I found that this iteration represented the data with the four elements: providing meaningful experiences, making selected information visible, making

connections and understanding. However, a further iteration was required as a theoretical perspective was applied as per chapter 6. Taking a mediational perspective highlighted that the element of understanding was pivotal to the remaining three elements, and hence the revised version now includes understanding as the central element, surrounding by the three elements of providing meaningful experiences, making selected information visible, and making connections. Both models were a product of the entire research process, from literature review through data generation and analysis, and theorising.

The next section describes the data annotations used for this research. I follow this by summarising the methods used.

Data annotations

Throughout the findings, I have used annotations to identify the data sources. These annotations are outlined in the below:

Table 1

Data source annotations

Data source	Alpha code
Name of teacher/Focus group 1	(Name/FG1) e.g., (Peter/FG1)
Focus group 2	(Name/FG2) e.g., (James/FG2)
Individual interviews	(Name/IN) e.g., (Mark/IN)
Centre documentation	(CD, year)
Field notes	(FN, dd.mm.yy)
Video data	(Name/VD e.g., (John/VD)

Summary

This section has explained the methods used for this research. Building on the previous methodology section, I began by discussing the nature of this research as drawing on ethnographic approaches in so far as visiting each centre over a prolonged period, but not being

at the centres every day. I described the participants and settings, then explained the process of data generation where I spent one morning each week at two centres for a period of six months, plus a further month at each centre as a familiarisation period. Data generation included participant observation through recording selected video footage, writing field notes, and taking photographs of pedagogical documentation, and facilitating and recording individual teacher and focus group interviews. I have explained the data analysis process as one which used thematic analysis, with a structured, five phase approach, and discussed the analysis for research questions 2 and 3 as involving deduction, induction and abduction due to the development of two models. Finally, I described the data annotation used throughout the findings. I now move on to discuss the ethics involved in this research.

Ethical Issues

Ethical considerations were continually reflected on throughout the research, including while planning, generating and analysing data, and in dissemination (Cullen, Hedges, & Bone, 2011). In effect, I was the ethical guardian and ethical decision maker for my participants, the centres, and the research process and practices (Braun & Clarke, 2013). Safeguards such as the University of Auckland Human Participants Ethics Committee approval process (approval #018057) and the advice of my supervisors aided my ethical decision making. However, day to day, and in-the-moment ethical decisions were firmly mine. My past employment as an ECE teacher, and my involvement in past research projects highlighted to me the responsibility that I held. These past experiences helped me foresee, and to some degree prepare for ethical dilemmas. Based on my prior teaching experience and as proposed by Gunn (2015), I drew on *Te Whāriki* to aid my ethical decision making. In *Te Whāriki*, children are viewed from a credit-based perspective as competent, capable learners, and this continued to inform my view of their working theory development. My view meant that I shifted the lens from conceptual accuracy of working theories to appreciating the process used in developing their working theories. This section describes my informed ethical decision making, beginning with ethics related to the participants, followed by ethics related to the research design and implementation.

In regards to the participants and based on the general principle of respect (Braun & Clarke, 2013), minimisation of harm, voluntary participation, informed consent and confidentiality have been, and continue to be paramount considerations. As I stated earlier, my participants included young children who I view as competent and capable learners in keeping with Gunn (2015). At the same time, young children can also be ethically vulnerable (Flewitt, 2005)

because decisions might be made for them and research could happen on or even to them rather than with them. Therefore, I considered ethics with additional care for the young children in this study.

The notion of minimisation of harm was uppermost in my ethical considerations during this project. The information from a qualitative research project could potentially harm the centres, teachers and children in terms of self-esteem, funding, and views of self by others (Miles et al., 2014). Practical strategies I have used throughout this research include engaging with the participants positively and warmly, being careful not to judge teachers or children, and making the research confidential. Minimisation of harm has been an issue I have considered and been aware of throughout the entire research. It will continue to be a priority for me as I publish from this thesis.

In addition to considering harm, I also considered the benefits that could be gained from this research. These benefits included highlighting the place of STEM education in ECE, enhancing teachers' awareness of, and use of teaching approaches, enhancing teachers' understandings about working theories, and therefore about *Te Whāriki*, and raising the profile of STEM education and working theories in the ECE sector.

Participant confidentiality has been an ethical consideration. Confidentiality can reduce the minimisation of harm to the participants; however, it can also remove the participants voices (Braun & Clarke, 2013). This dilemma was foremost in my mind as I grappled over the decision making between confidentiality or the principle of credit, particularly knowing that video data was to be generated. Due to the everyday context, the young children involved, and the exploratory nature of this research I decided to use pseudonyms for the participants and centres. Theoretically, the centres and participants are not identifiable, however I acknowledge and made clear to the participants that due to the relatively small ECE community in Auckland, I could not guarantee that the centres and children are not identifiable. Actual words reported in this research, and community knowledge of the project meant that anonymity could not be offered. I presented this information both through interactions with teachers and children's parents, and in the participant information sheets (PIS)—see Appendix B. Primarily my goal was to enable the participants to be informed about the research, and hence provide informed consent which I detail next.

Guided by the principle of respect, the notion of informed consent was a significant concern for this research. The flexible and adaptive nature of qualitative research means that informed

consent becomes a complex issue (Braun & Clarke, 2013). Gaining informed consent was an ongoing process throughout the data generation involving making the nature of the research known, the expectations involved, the possible outcomes, and likely dissemination (Cullen, Hedges, & Bone, 2011; Yin, 2018). Gaining informed consent was a multiple stage process. First, I gained consent from the owners of each centre. Next, I explained the project to the teachers of each centre, making the PIS and consent forms available.

After gaining teacher consent, I then gained consent for the children's participation. This stage of consent occurred during the one month familiarisation period. During this time, I made connections with parents and whanau (extended family), began developing relationships with teachers and children, and explained my research. I provided a letter (see Appendix A) for each family explaining the research and introducing myself, and made the PIS (see Appendix B) and consent forms (see Appendix C) available. The one month familiarisation period meant that I was under little pressure to gain consent immediately. It provided time for children, parents, whānau and teachers to learn about me and my research without feeling investigated, scrutinised or that data was being recorded. As I discussed earlier, because I used video recording, I regarded all children as my participants as they might be in the video footage. Therefore, PIS and consent forms were issued to all children's families. Gaining consent was a continuous process as new children enrolled at the centres throughout the research. I talked with administration staff and teachers every visit to identify each new family and to ensure that PIS and consent forms were made available to them. The children's families were informed that consent was ongoing, and that they could temporarily or permanently opt out of the research at any time up until two weeks after data gathering had concluded as per the PIS (see Appendix B). Similarly, the teachers were also informed that they could temporarily or permanently opt out of the research at any time up until two weeks after data gathering had concluded. In the case of the teachers, their focus group data would be retained. The teachers demonstrated their understanding of temporarily opting out, at times asking me to stop recording data. In the early stages of the research design, I had planned to undertake home visits, where I would interview each teacher at their home. The purpose of these visits was to gain a deeper understanding of the teachers' culture, background and upbringing. However, during the consent process, only one teacher agreed to the home visits, therefore home visits were not undertaken. I felt that informed consent should extend to children. Based on my views of children as competent and capable, I also felt that they should have a voice in their participation as I discuss next.

Under the principle of respect, and based on my previous teaching and research experiences, I felt that only parental consent for children was not adequate. As the research was undertaken with children, I felt that children should have a right to decide whether they participated in the research. Therefore, I gained children's informed assent as I describe next.

An important premise of my research was that I was researching with my participants, not on, at, or to them. This premise then meant that I needed to consider whether the young children should have the right to decide if they participated in this research. The question of whether children can provide consent and participation rights, and whether children can fully understand the scope, methods, nature and consequences of participation has been raised by Gunn (2015). She posited that factors such as insufficient time and a lack of expertise at talking with children can exacerbate children's consent, but that these factors can be overcome. My approach to children's decision making about participation aligned with Gunn's. As she did, I produced simple resources for the children detailing the research. Drawing on my teaching and research experience, I created a simple booklet (Appendix B4) which I read with individual or small groups of children. The children were often very interested in the booklet, asked many questions and we spent prolonged times discussing the research and their part in it. The one month familiarisation period enabled me to freely engage in these discussions without feeling pressure to be generating data.

I also decided that the children should have the right to grant (or not) assent to be part of this research. Consistent with Flewitt (2005), I viewed children's assent as ongoing and provisional. The first stage was to gain assent in a formal way, through an assent form. Drawing on my experiences as teacher researcher from a previous research project (Hedges & Cooper, 2014a), and Dockett, Perry and Kearney's (2013) work on children's assent, I created a simple assent form (see Appendix D). The form included an area for the children to colour in spaces denoting whether they agreed to be part of the research or not. While I acknowledge that often the children may have agreed to participate to please me, or through peer pressure, I saw many children take their participation rights seriously as they discussed it with me, their peers and their teachers. A poignant moment in this process was when a 4-year-old child seriously filled out her own form, then took a second form home for her baby brother to fill out as he had been away that day. The second stage recognised that children's assent might be provisional, and could be withdrawn at any time. This meant that I was constantly aware of the need for children's assent in data generation. Aligning with Bourke and Loveridge's (2013) thoughts, this also meant looking for children's dissent because they might have been unwilling to

participate in the moment, but not able to express it. In practice, I addressed the issue of ongoing child assent through discussion with, and careful observation of the children. Rather than asking for their assent every time I generated data which I thought might influence and alter the data, the children and I discussed that they could tell me to stop recording and/or move away at any time. Occasionally, the children would do this. I also carefully observed children's body language and facial expressions to interpret implicit assent before and during data generation.

Voluntary participation was a key part of this research. Directly after meeting teachers the first time to discuss the research, most teachers wanted to return the completed consent forms immediately. However, to avoid peer pressure, and to enable reflection, to allow the teachers time to discuss the project without me, and therefore to allow better informed decision making I advised that I would return a week later to collect consent forms. A week later I returned to find all consent forms were filled in by the teachers. Parental consent forms were more challenging as again I advised parents to take the forms home to discuss with other family members. Sometimes these forms were not returned, and my challenge then became to sensitively ask about the consent form without placing a demand on the parent and removing their ability to participate voluntarily.

This section has explained the ethical considerations for the research. I have explained how the principle of respect has underpinned my thinking and decision making about minimisation of harm, voluntary participation, informed consent and confidentiality. I readily acknowledge that these considerations do not end with the publishing of a thesis, but will continue to hold these considerations through any further dissemination related to this research. I now move on to the final section of this chapter which discusses issues of trustworthiness.

Trustworthiness

Trustworthiness of interpretivist, qualitative research is a measure of the confidence that can be attributed to the research design, approaches used, and findings (Given, 2008). To provide confidence for the reader about the design, process and findings of this research, I have drawn on the work of Guba and Lincoln (1989). They argue that the trustworthiness of qualitative research can be assessed from four criteria: credibility, transferability, dependability, and confirmability. This section outlines the trustworthiness of the study in terms of the four criteria

Credibility

Credibility is a criterion used in qualitative research to show that the findings of the research are congruent with the reality of that which was researched (Given, 2008; Shenton, 2004). Credibility is therefore a critical factor towards assessing trustworthiness of the research. Aspects such as identifying the background and qualification of the researcher; developing early familiarity with the participants culture; using well established methods; and using triangulation (Guba & Lincoln, 1989) are commonly used to strengthen credibility. Therefore, I have described and explained these aspects as they apply to my research in order to strengthen the credibility, and therefore trustworthiness of this research next.

To explain and establish my background and qualification as a researcher, I have described my prior interpretivist, qualitative research experience and seven years ECE teaching experience in chapter 1. In short, I have been involved in my master's research as an ECE teacher-researcher where I investigated children's working theories (Lovatt, 2013). I have also been involved in two large scale research projects as an ECE teacher-researcher in association with other teachers and academics (Hedges & Cooper, 2014a; Podmore, Hedges, Keegan, & Harvey, 2015). Through my prior research, I have published articles and chapters (see chapter 1) and presented many times about my research. Furthermore, in chapter 1, I explained how I became a working theories researcher, my epistemological stance, and the conceptual framework for this research. I therefore argue that I have experience of the ECE centre contexts that I researched within, and that I have experience as an interpretivist, qualitative researcher.

From very early in the research design, and as I have explained earlier in this chapter, I was clear that I should spend a prolonged period of time in familiarising myself with the ECE centres and the participants. I believe that this familiarisation period strengthened the trustworthiness of the research as it enabled me to develop relationships with participants, and understandings of culture and routines without being under pressure to generate data. It meant that I could explain the purpose of the research clearly and sensitively to the prospective participants. The prospective participants could therefore gain an in-depth understanding about the design and purpose of the research, and make informed choices about their participation.

This study has used well established research methodology and methods. My decision making about the methodology and methods was based on four factors. First, on the methods used in prior research that investigated working theories, and as I have detailed in the literature review sections of chapters 3, 4, and 5. Second, on my prior experience in the two large research

projects detailed in chapter 1. Third, on my prior experience as a researcher for my master's research, again as detailed in chapter 1. Fourth, on research literature. Together with advice from my supervisors, I argue that this these four factors mean that my research uses well established methodology and methods that strengthens the credibility of the study.

In addition to well established methods, triangulation strengthened the credibility of this research. Triangulation is a method of confirming findings, and involves generating data from multiple sources of evidence (Yin, 2018). There are five distinctions regarding triangulation: data source, method, researcher, theory, and data type (Miles et al., 2014). For this research, multiple data sources included teachers and children across two ECE centres, and over a six month time period. A range of methods were used including participant observation, interviews, focus groups and pedagogical documentation. I was the sole researcher, meaning that triangulation could be argued as weak under this distinction. The same biases used in generating data from one source might apply to the other sources too. While bias can never be removed, the prolonged period of data generation meant that deep, rich data was generated over time, and without pressure to produce data. In addition, my statement regarding my positioning in this research describes my identified biases. Therefore, as I argued earlier, I acknowledge that my bias did shape my research design and process, however I also argue that this bias did not reduce the trustworthiness of the results and conclusions. The support of two supervisors, and the engagement in informal conversations with participants and the re-viewing of video data during teacher interviews also strengthened researcher triangulation. Multiple data types have been used ranging from audio and video data to photographs of documentation. Because I have argued that triangulation is strong for these five distinctions, I argue that the triangulation, and hence the credibility of this research is strong.

I argue that because the four areas of credibility—background and qualification of the researcher; development of early familiarity with the participants' culture; well established methods; and triangulation—are strong, that the trustworthiness criterion of credibility is therefore strong. I now move on to the second criterion of trustworthiness: transferability.

Transferability

Transferability relates to the "extent to which (aspects of) qualitative results can be 'transferred' to other groups of people and contexts" (Braun & Clarke, 2013. p. 282). Importantly, the notion of transferability means that the reader makes decisions about the transferability of the findings to their context (Merriam, 2009). The nature of qualitative

research means that the context is critical. Because every context is different, an argument could be made that the findings cannot be transferred. However, this research has focused on the processes of working theory development, in regards to the child's development and the teachers' approaches. Maxwell (2013) noted that processes may be transferable across diverse contexts and settings. Hence the findings of this research could be transferable to other contexts. In addition, the models I have developed illustrate one way that working theories were developed by the participants in this study, and one way that the teachers enriched the children's working theories. I make no claim that this is the only way, indeed that claim can never be made. However, I argue that the transferability of the findings in strengthened because the research focused on processes, and was undertaken in two diverse ECE contexts. Therefore, the readers of this research could find that the models and the theoretical explanations developed through this research, in everyday ECE contexts explain the process of working theory development and enrichment in other contexts, and at the very least provide a basis for future research.

Dependability and confirmability

The criteria of dependability and confirmability overlap. Dependability is a criterion that focuses on the researcher making the research methods and processes clear, enabling future researchers to repeat the investigation (Guba & Lincoln, 1989). To strengthen the dependability of this research, earlier in this chapter I have described, explained and justified the methodology, methods and techniques used. I have also described in detail the data generation and analysis process that I undertook. By doing so, I have attempted to be transparent about my natural leanings, interests and possible researcher bias. I acknowledge that these are all issues that must be recognised as they cannot be removed. I suggest that by recognising and making these issues explicit, the trustworthiness of this research has been enhanced. Furthermore, I argue that these issues can also be viewed as a positive aspect of interpretivist, qualitative research as they are part of a complex, rich experience and process leading to subjective, varied and multiple meanings leading to a complex view of the topic (Creswell, 2014). Confirmability is a criterion that highlights that the findings represent the experiences and the ideas of the participants, and not of the researcher (Shenton, 2004). To strengthen confirmability, I have explained my background, beliefs, methodology, and underpinning decisions through this chapter and chapter 1. I argue that I have therefore also strengthened the dependability and confirmability of this criteria.

Based on Guba and Lincoln's (1989) four criteria of trustworthiness I argue that the trustworthiness of this research is strong. I have explained how each criterion is addressed in this study, and argue that because each criterion is strong, then the trustworthiness of this study is therefore strong.

Summary

This chapter began with the Māori proverb *"Tē tōia, tē haumatia"* meaning that nothing can be achieved without a plan and design. This chapter has explained and justified the plan and design of the research by describing the methodology and methods used. The methodology aligns with the conceptual framework underpinning the research, with STEM research principles, and prior working theory research methodology. I have viewed knowledge as context bound, being socially, culturally, and historically constructed and therefore subjective. Simultaneously, I have acknowledged the real, knowable world within that context. I have used an interpretivist, qualitative approach to delve into, interpret and understand the real, knowable, yet subjective world of STEM related working theories.

Using a case study which draws on ethnographic approaches, and spending prolonged time in everyday research settings has enabled the development of rich understandings which address my research questions. Focusing on the unit of analysis as being working theory development, over six months I have spent one morning in each of two ECE centres every week. Multiple data sources have been used, and exhaustive data has been generated.

Data generation focused on participant observations of teachers and children using video recording and field notes. After an initial one month familiarisation period, I spent the ensuing six months both participating in and observing 3 and 4-year-old children and their teachers at two ECE centres in Auckland, New Zealand. Focus group interviews and individual teacher interviews for teachers at both centres were undertaken. Pedagogical documentation such as meeting notes, wall documentation, and children's learning stories were also recorded.

Thematic analysis has been used to analyse the data. After organising the data, I used QSR NVivo for data management and as a coding tool. Simultaneously, I used a process of deduction, induction and abduction (D-I-A) to recursively build and refine the models, moving between theory and data. A five stage process of compile, disassemble, reassemble, interpret, and conclude (Yin, 2015) was used to provide structure to this recursive process.

I have described the issue of trustworthiness, in particular focusing on credibility, transferability, dependability and confirmability (Guba & Lincoln, 1989). I have explained how the research addresses each criterion and argued that because each criterion is strong, that the trustworthiness of the research is strong. As this research focuses on processes, I have argued that the findings, conclusions and models might also be transferable to other contexts, and at a minimum, a starting point for further research. I now move to chapter 3 which is the first of three chapters which respectively address research questions 1, 2 and 3.

3. Teachers' perceptions of STEM in ECE

"[STEM is] everywhere but you still have to breathe it…It still has to be made visible." (Deborah/FG2).

Introduction

This chapter addresses the first research question: How do teachers perceive the place of STEM education within ECE? It is important to understand and explore teacher perceptions of STEM because STEM domains provide the context in which this research is carried out, thus. As noted in chapter 1, and similar to the upcoming chapters 4 and 5, this chapter is not a typical thesis findings chapter. Instead, it includes a literature review, findings, and discussion. The findings are subsequently theorised and explained in chapter 6. To begin with, this chapter presents a rationale for the place and investigation of STEM (science, technology, engineering, and mathematics) education in ECE. Next, I critically review literature related to STEM education in ECE, then present findings related to the research question.

Education in the early years is critical to developing and shaping children's ongoing interests and understandings that stay with them throughout their lifetime (Fleer, 2010; Wylie et al., 2006). STEM education in the early years therefore has the potential to build fundamental knowledge, skills, and attitudes that lead to ongoing STEM related interests for children (Lindeman, et al., 2013; Saracho & Spodek, 2008a). My doctoral research investigated young children's working theories within the context of STEM education. I have focused on the development and associated teaching approaches of working theories about the STEM domains. Chapters 4 and 5 respectively address the development of working theories and teaching approaches. Before I get to those chapters, first I address ECE teachers' perceptions of STEM in this chapter. Investigating teachers' perceptions is an important part of this doctoral research as it provides a foundation for building the remainder of the research. If teachers perceive STEM negatively or as low priority, they may be reticent to engage in teaching and learning experiences, or perhaps engage in these experiences under duress (Kumtepe & Genc-Kumtepe, 2015). Their feelings might be passed on to the children either directly, or through the absence of STEM related experiences, activities and interactions. Alternatively, positive perceptions of STEM likely lead to genuine desires to notice STEM related interests and learning, and to engage authentically in these experiences, passing on positive attitudes, and

building knowledge about STEM. This chapter therefore addresses research question 1: How do teachers perceive the place of STEM education within ECE?

A rationale for STEM education

The demand for a focus on STEM education has been driven from an economic and political perspective in Western countries (Blackley & Howell, 2015). The political and economic perspectives are intertwined, as the political interest and investment in STEM education and related careers is economically driven (Blackley & Howell, 2015; Marginson et al., 2013). STEM education is seen as a way to advance technological and economic standing, and to better inform a country's understanding and decision making of STEM related issues. This perspective drives government focus, policy and funding both internationally and in New Zealand.

Aligning with global views, the political focus on STEM education in New Zealand appears to have been motivated by what STEM education can lead to, not how to teach or learn about it, or even what STEM really is (East & Tolosa, 2015). This focus was highlighted by Buntting, Jones, McKinley, and Gan (2013) who noted, "the New Zealand Government, like many governments around the world, appears to be placing increasing emphasis on the role of STEM related research and development for economic and social development." (p. 22). According to the Ministry of Business, Innovation and Employment [MBIE], STEM education enables greater career choices, is a driver of innovation, and provides students with transferable skills and processes to better understand the world (MBIE, 2014). From a political and societal perspective then, STEM education is seen as leading to both an individual's education and expertise, and to New Zealand's economic growth and prosperity. However, STEM education potentially provides far more benefits than purely economic as I explain next.

People who understand and think critically about the fundamentals of STEM concepts, can better understand the world, and make informed decisions about the issues and challenges at hand (Dierking & Falk, 2016). Certainly, these issues and challenges include economic factors such as employment, however they extend to further individual and societal benefits. For example, at the time of publishing this thesis, a global coronavirus epidemic was taking place, requiring the cooperation and understandings of epidemiologists, scientists, economists, politicians and the public in general. An understanding of STEM concepts enables people to be contributing members of society (English, 2016). These understandings then enable

engagement in decision making and negotiation about issues such as health and the environment (Hodson, 2009). Being a contributing member of society who understands and engages in decision making about STEM related issues potentially aids wellbeing, fulfilment, health and enjoyment of life. Therefore, STEM education has the potential to lead to positive benefits for individuals, communities, countries and the world. Because of the potential benefits, STEM education should be learnt and taught as early as possible (Wylie et al., 2006), and as I argue next, should be an integral part of ECE.

In the early years, basic understandings and positive attitudes are developed which influence ongoing achievement, efforts and attitudes throughout later schooling (Bybee, 2013; Linder et al., 2011; Wylie et al., 2006; Zucker et al., 2016). A positive introduction to STEM education in the early years could therefore provide a foundation for ongoing interests and learning (Kumtepe & Genc-Kumtepe, 2015). However, internationally, and within New Zealand, STEM education research focuses on public schooling, particularly secondary and tertiary levels (MBIE, 2014; National Science and Technology Council, 2013). The focus on research in later schooling could be expanded to include ECE settings, adding depth to STEM education research by including younger children.

In the New Zealand ECE context, local curriculum is woven primarily around children's strengths and interests (Lee et al., 2013). The non-prescriptive nature of the curriculum provides an ideal setting for teachers and children to experience meaningful STEM teaching and learning opportunities. At the same time, weaving a local curriculum places an onus on teachers to identify and build on children's strengths and interests. Their strengths and interests might not be STEM related. Furthermore, teachers might naturally foreground other learning areas due to their own strengths, interests, and attitudes. Therefore, I argue that STEM education in NZ ECE is a complex space, dependant on teachers, children and their families' strengths, interests, and attitudes. Empirical research about fostering STEM education in ECE is therefore required as I explain next.

Understanding how STEM education can be taught and learnt is necessary to provide an insight into what STEM education in ECE might entail. These insights can then provide a foundation for teaching approaches to be built on which could enhance children's learning about STEM. My research aims to add to the developing understandings about STEM education by investigating the development of working theories and associated teaching approaches within

the context of STEM. In the next section, I critically examine STEM related literature to construct my definition of STEM education for this research.

STEM in ECE

STEM education is viewed in literature as involving both individual and integrated domains. Many overlaps, yet distinctions between the domains have been noted (Bagiati & Evangelou, 2015; Lindeman et al., 2013; van Meeteren & Zan, 2010). To develop a definition of STEM education for this research, I first provide an explanation and example of each domain. I use water play—specifically the involvement of children at a raised water trough—to provide possible examples of the STEM domains in everyday learning experiences.

Science

Science has long been considered a part of the ECE curriculum and includes conceptual, procedural, and attitudinal knowledge about the natural world (Campbell et al., 2015). In short, science can be thought of as "a body of knowledge that provides the best available explanations of the natural world." (French & Woodring, 2013, p. 180). Examples of science in ECE include the physics of movement such as jumping and throwing; earth and space science such as gravity, stars, and planets; and seasons such as leaves dropping during autumn. An everyday example of science in ECE is during water play where concepts such as floating, sinking, and viscosity are explored.

Technology

Literature on technology in early childhood contexts is less common, being considered a relative newcomer to ECE (Cunningham & Higgins, 2014). Technology is "the designing, building, and use of tools by humans to solve a problem or to make life easier" (Lindeman et al., 2013, p. 100), aligning with the notion of problem solving in early childhood. Within the New Zealand context, Mawson has written most about technology for young children (e.g., Mawson, 2003, 2007, 2011). Examples of technology in ECE include knowing how and why things work, and engaging in exploratory play, and problem solving. An everyday example of technology in ECE is during water play where children might find—or make—tools such as funnels to enable the filling of containers.

Engineering

The literature on engineering in early childhood settings is sparse, particularly in New Zealand. Engineering has a close relationship with technology (Saracho & Spodek, 2008). Problem solving skills connect with domain knowledge to construct, test solutions, and make evaluations (Lindeman et al., 2013). Engineering involves both design and habits of mind (van Meeteren & Zan, 2010) and is "a disciplinary domain that uses mathematics, science, and technology as tools following an integrative approach" (Bagiati & Evangelou, 2015, p. 113). Through engineering, young children can problem solve, learning through success and failure (English & Moore, 2018). An everyday example of engineering in ECE is during water play where children might problem solve to design, construct and evaluate a way to transfer water between containers or water troughs.

Mathematics

Mathematics has been a traditional part of early childhood curriculum. Early childhood mathematics encompasses concept, method and language, focusing on number, geometry, measurement and algebra (Ginsburg & Amit, 2008), comparing, estimating, measuring, and patterns (Brenneman, Lange, & Nayfield, 2019). Within New Zealand ECE contexts, the notion of Te Kākano (the seed) introduced six strands of mathematical learning: patterns, measuring, sorting, locating, counting and grouping, and shape (MOE, 2010). Learning about mathematics can occur through everyday experiences such as gardening (McChesney, 2017) and includes counting, adding, and subtracting (Ginsburg & Amit, 2008; MacDonald, 2013). An everyday example of mathematics in ECE is during water play where concepts such as comparison between containers, shapes and sizes, and estimations of container volume are explored. Like science, mathematics encompasses wide areas of learning relevant to early childhood settings.

Further acronyms

Further alternatives to STEM education that reflect other attempts to integrate domains include STEAM, STREAM, and STREAM+. STEAM education (Lindeman et al., 2013) has been offered as a way to introduce creativity into STEM by way of a focus on the arts—hence the addition of the letter A. STREAM education refers to either science, technology, robotics, engineering, and mathematics, or science, technology, reading and wRiting, engineering, arts, and mathematics (Stubbs & Yanco, 2009). STREAM+ education replaces reading and wRiting with research, but through the addition of the + sign, includes "science, technology, research,

engineering, art, math, plus any other content area, theme, or learning goal" (Andria, 2019). For the purpose of this research, and to provide a context and boundaries for this research, I have focused on STEM education.

Integrated STEM

While STEM education consists of individual subjects, there are calls for STEM to be taught and learnt as an integrated whole (Lindeman et al., 2013; Marginson et al., 2013). Two main arguments underlie these calls. First, there are natural overlaps between the elements, particularly in project approaches to teaching and learning in ECE (Katz, 2010). Second, the world is no longer conceived of as operating in discrete disciplines, instead being regarded as large, complex, inter-related systems (Blackley & Howell, 2015; Conner, 2013). An understanding of integrated STEM could enable greater and more meaningful understandings of the systems, leading to motivations for teaching and learning. However, not all scholars agree with this position. For instance, Bybee (2013) argued that STEM domains should remain separate disciplines as they come with non-transferable ways of knowing, and integrated approaches could lead to watered-down versions of each discipline being taught. Bybee's (2013) rationale for his argument against integration could also be viewed as a resolution between integration and separation of STEM domains. He argued that in-depth understandings of each discipline are required before integration can take place, leading to ramifications for teachers: teachers with deep subject knowledge of each discipline could integrate the STEM domains. However, the issue of teacher subject knowledge is complex, particularly in ECE settings where topics and themes for teaching and learning often proceed from children's interests (Fleer, 2010). Further research is required into how ECE teachers might gain subject knowledge of each STEM domain, recognising that there are multiple topics and themes within each domain, and further that there are many other learning areas in ECE.

Integrated STEM has different forms. Bybee (2013) argued that integrated STEM could focus on the connections between the domains, seeing them as either complementary and overlapping, or separate but still incorporated in one learning experience. Blackley and Howell (2015) define integrated STEM simply as a learning experience including two or more of the STEM domains, for instance involvement in technical design that is based around a scientific inquiry. My definition of STEM education for this research draws on Blackley and Howell's explanation of a minimum of two domains.

STEM education can also be regarded as an integration of process and outcome which aligns with Krieg's (2010, 2011) thoughts and which I explain later in this chapter. It can also be regarded as an integration of process, outcome, and attitude (Katz, 2010). As I outlined in the introduction chapter, these three aspects are all essential to STEM. From this perspective, when engaging in STEM learning, a child would be developing outcomes in the form of subject knowledge. They would also be developing process knowledge as they develop skills to use their subject knowledge both to solve problems and to develop further subject knowledge and skills. Finally, they would also be developing attitudes (ideally positive) towards their understandings, their use of their understandings and towards further development of outcomes and processes related to the STEM domains. These aspects are consistent with the aspects of working theories as I explain next.

The multiple aspects of STEM education— process, outcome, and attitude (Katz, 2010)—align with the aspects of working theories. As I explained in chapter 1, working theories are tentative and evolving ideas and understandings, described in *Te Whāriki* as a combination of three aspects: knowledge, skills, and attitudes. These three aspects are consistent with the aspects of STEM as outcome and knowledge can be considered similar, process and skills can also be considered similar, and both STEM and working theories involve attitudes. Therefore, there are consistencies between STEM education and working theories, particularly when focusing on working theories about the STEM domains which is the context of this research. To provide a basis to the context of this research, it is important to define and explain my use of STEM education which I do next.

A definition of STEM education

Because STEM education is ambiguous and means different things to different people, it is important to be clear and transparent about my definition for this research. I have drawn on the literature to build a definition for my research as below:

STEM education represents the knowledge, skills, and attitudes about science, technology, engineering and mathematics that are taught and learnt in early childhood settings. STEM education occurs when a combination of two or more of the domains are integrated together in teaching and learning experiences.

For this research, STEM teaching and learning is therefore multi-faceted. It highlights knowledge, skills, and attitudes about the STEM domains, and can focus on any one of those

facets, or all three together. In addition, I perceive STEM teaching and learning as encompassing two or more of the STEM domains. This means that STEM related teaching and learning focuses on knowledge, and/or skills, and/or attitudes related to two or more of the STEM domains.

Up to this point, I have developed a definition of STEM education for this research by reviewing literature, describing the multi-faceted nature of STEM, explaining the individual domains and STEM as an integrated whole. Next, I review literature related to teachers' perspectives about STEM, which is the focus of research question 1, and which I address in the findings section later in this chapter.

ECE teachers' perspectives of STEM education

It is essential to understand teachers' perspectives about STEM education in ECE as perspectives guide everyday decision making (DeJarnette, 2012). Teachers' perceptions of STEM influence their likelihood to take up potential STEM-related teaching and learning opportunities. In the USA, a study investigated teachers' implementation of a problem-based STEM curriculum for 3 to 5-year-old children (John, Sibuma, Wunnava, Anggoro, & Dubosarsky, 2018). This study reported that teachers' attitudes about STEM correlated to their involvement in STEM-related teaching. Similarly, in a study of ECE science and mathematics curricula design in the USA, Kinzie, Whittaker, McGuire, Lee, and Kilday (2015) reported that teachers' beliefs about young children's early development also afford or constrain teachers' involvement in mathematical and scientific teaching and learning. Positive teacher perspectives towards STEM can lead to teachers looking for, and taking up opportunities to engage in STEM related teaching with young children (Bagiati & Evangelou, 2015). Conversely, negative perspectives of STEM can lead to the minimisation, or avoidance of STEM related teaching opportunities altogether (Park, Dimitrov, Patterson, & Park, 2017). This avoidance has been termed STEM-phobia (McClure et al., 2017). Teachers' perceptions of STEM therefore influence their curricula decision making in regards to STEM education. It is essential then that teachers' perceptions about STEM education in ECE be investigated.

In particular, in the New Zealand context where teachers use a non-prescriptive curriculum, an onus is placed on teachers to make informed decisions about teaching and learning opportunities that they engage in. In *Te Whāriki*, teachers are encouraged to draw on their pedagogical knowledge, and on their understandings of children to negotiate curriculum

decision making with families and children. Teachers' decision making is then paramount, hence factors which influence their decision making should be investigated. This research investigated one of those factors—teachers' perceptions of STEM education.

Limited research was located that investigates ECE teachers' perceptions of STEM education. Using a quantitative survey involving 830 ECE teachers in the USA, Park et al. (2017) found that 70% of participant teachers had positive views towards STEM education in ECE, including views that STEM education is critical because it builds foundations for concepts, knowledge, and skills. They also reported that 30% of the participants did not think that STEM education was appropriate or important in ECE. Uğraş and Genç (2018) reported on a mixed-methods study investigating the perceptions of 35 preservice ECE teachers' perceptions of STEM education in Turkey. They reported that the teachers in their study generally held positive views of STEM education, and that STEM education provides children with theoretical knowledge, problem solving skills and can be an intersection between theory and practice for the children. The teachers were concerned that their lack of STEM related knowledge, behavioural issues of children, and a lack of time might constrain their implementation of STEM education. Further research is needed to investigate teachers' perceptions about STEM in different contexts, and to further determine the effect of STEM perceptions on STEM education.

While there are few studies that investigate ECE teachers' perceptions of STEM, there are numerous studies that investigate factors that influence ECE teachers' engagement in STEM education. In particular, the literature highlights that teacher engagement in STEM education is affected by subject knowledge, pedagogical content knowledge, and confidence as I explain next.

Subject knowledge about the STEM domains enables teachers to understand and extend children's interests and concepts (MacDonald & Rafferty, 2015). Conversely, a lack of subject knowledge could hinder teachers from becoming involved in STEM related experiences, potentially resulting in missed opportunities (DeJarnette, 2012; Kumtepe & Genc-Kumtepe, 2015), and could be considered as an obstacle, or barrier to children's learning (Brenneman et al., 2019). Coupled with the nature of *Te Whāriki* as a non-prescriptive framework, where teachers negotiate local curriculum, a lack of subject knowledge could lead to potential STEM teaching and learning opportunities being missed or avoided. However, at the same time, a non-prescriptive framework provides opportunities for teachers and children to teach and learn together, unconstrained by a curriculum that requires a focus on academic knowledge. Together

with teachers who hold some subject knowledge about STEM, and a desire to learn together with children, the possibilities for STEM related teaching and learning are positive.

The notion of ECE teacher subject knowledge is complex, contestable, and debatable (Hedges, 2014a; Krieg, 2010, 2011). In ECE centres working with a curriculum framework, where local curriculum is negotiated, a teacher cannot be expected to hold encyclopaedic subject knowledge. Children are diverse and bring a multitude of interests with them. Teachers cannot be expected to know everything about everything. Campbell and Howitt (2015) addressed this issue somewhat, stating that teachers need a basic understanding of key scientific concepts to support children's learning. However, they did not identify the basic concepts, and perhaps because of the breadth of children's interests, that is impossible to define. In contrast, and as I noted earlier, Bybee (2013) argued that in-depth understandings of each domain are required by teachers. As Bybee did not explain what in-depth understandings actually entail, this argument remains problematic.

Krieg (2010, 2011) offered a potential solution to the dilemma of teacher subject knowledge. She first argued that the process and outcome of learning are equally valid. She then argued that teachers could position themselves as critical mediators of knowledge. In this regard, teachers could focus on inquiry, comparing and contrasting children's knowledge with theoretical knowledge that has been generated beforehand. By doing so, teachers and children could then develop deeper levels of complexity and understandings. Krieg's thinking resonates with the theoretical explanation of mediation which I use to theorise the findings in chapter 6.

Pedagogical content knowledge (Shulman, 1987) is also required to teach STEM education in ECE (MacDonald & Rafferty, 2015). Pedagogical content knowledge is a three-fold notion involving subject knowledge, knowledge of children's understandings about the subject, and knowledge of ways to present the subject (Hedges & Cullen, 2005; Shulman & Grosman, 1998). Pedagogical content knowledge enables enrichment of subject knowledge to provide rich opportunities for learning (Brenneman et al., 2019; Kumtepe & Genc-Kumtepe, 2015). Subject knowledge enables teachers to present learning, then pedagogical content knowledge enables enrichment of learning opportunities (Kumtepe & Genc-Kumtepe, 2015). In short, teachers need to understand what the child knows already about the concept, understand the concept themselves, and know how to use their subject knowledge to engage in teaching and learning in their ECE setting. Hence the relation with subject knowledge is paramount. Pedagogical content knowledge is related to teacher confidence which I discuss next.

Teacher confidence about STEM education has been found to relate to subject knowledge and pedagogical content knowledge (McClure et al., 2017). Studies found that many ECE teachers report low STEM related subject knowledge (Bagiati & Evangelou, 2015; Kumtepe & Genc-Kumtepe, 2015; McClure et al., 2017) which negatively impacts children's learning about the STEM domains as teachers focus on other learning areas such as literacy and social-emotional which they are more confident about (Brenneman et al., 2019). Teacher confidence has also been found to be adversely impacted by negative attitudes towards STEM (McClure et al., 2017), past teaching and learning experiences, and misconceptions (Kumtepe & Genc-Kumtepe, 2015).

In addition to teacher perceptions, prior international research has identified multiple barriers that constrain teachers' engagement in STEM education. Practical limitations such as time and children's attendance (Bagiati & Evangelou, 2015), increasing political demands to focus on academic outcomes (Lippard, Lamm, Tank, & Choi, 2019), a focus on following children's interests (Tippett & Milford, 2017), a priority on social-emotional learning (Kumtepe & Genc-Kumtepe, 2015; Simoncini & Lasen, 2018), a focus on literacy learning (French & Woodring, 2013; Kumtepe and Genc-Kumtepe, 2015), and competing academic skills and teachers' limited backgrounds (Lippard et al., 2019) have been identified as being potential barriers to engagement in STEM teaching and learning. Therefore, there are many factors that limit the involvement for both teachers and children in STEM related teaching and learning experiences.

A curriculum document influences teachers' decision making (Pinar, 2012). It could then be argued that curriculum influences teachers' perspectives of subjects and content such as the STEM domains. Within *Te Whāriki*, mention is made of science and mathematics, and to a lesser degree, to technology. Engineering or STEM are not mentioned. For example, in the document it states that children construct knowledge by drawing on "cultural, aesthetic, historical, social, scientific, technological, mathematical and geographical information" (MOE, 2017, p. 22); and "equipment is provided for scientific, mathematical and technological learning." (p. 50). The term STEM, or engineering is not immediately evident. However, because *Te Whāriki* is a framework, it enables a focus on negotiated local priorities which can feature engineering and integrated STEM teaching and learning.

A long-standing discourse in ECE is that curriculum should be built around children's interests. On the surface, this premise appears a sound counter to prescribed academic outcomes that may have little relevance to individual children. However, the notion has been termed

problematic by Hedges and Cooper (2015) who called for the introduction of conceptual frameworks and analytical interpretations of children's interests. Without a rigorous analysis, teachers risk trivialising children's interests, and building curriculum that is not soundly situated on the interests of the children. The notion of children's interests is important to my research, as the teachers frequently mentioned the importance of relying on children's interests when planning for their learning.

Children will learn about STEM whether teachers engage in it or not (McClure et al., 2017). However negative issues of confidence, subject knowledge, pedagogical content knowledge, and multiple learning areas will result in missed opportunities to engage in STEM related teaching and learning opportunities (Lippard et al., 2019). Conversely, investing in STEM related subject knowledge and pedagogical content knowledge could build teachers' understandings about STEM and its importance in ECE. These understandings could improve teachers' confidence to become involved in teaching and learning experiences potentially related to STEM, and increase the priority placed on such experiences.

A common theme throughout the literature is that STEM education can be integrated into existing curriculum, play, and interests without requiring significant change in curriculum or teacher approaches (Bybee, 2013; MacDonald & Rafferty, 2015). This perspective means teachers might need to change their perspective of teaching and learning experiences to focus on the STEM learning that is occurring for the child. Focusing on the aspects of STEM learning which I earlier identified as process, outcome, and attitudes also aligns with the aspects of working theories which I identified as knowledge, skills, and attitudes. Therefore, a repositioning of teachers' perspectives towards children's learning could lead to a focus on children's developing working theories about the STEM domains.

In this chapter, I have explained the place of STEM education in ECE, arguing that STEM education is appropriate and relevant for young children. I have explained each domain of STEM, then brought together the domains to provide an explanation and definition of integrated STEM education in ECE. I have argued that teachers' perceptions of STEM education in NZ ECE is a critical but under-researched aspect which influences their curricula decision making. I have argued that teachers' subject knowledge, pedagogical content knowledge, and confidence are potential barriers to STEM related teaching and learning experiences. I now move on to present the findings from this study which are related to teachers' perceptions of STEM education in ECE.

Findings

This section identifies findings addressing research question 1: How do teachers perceive the place of STEM education within ECE. The findings bring together data from teacher interviews, pedagogical documentation, and participant observations. I begin this section by outlining teachers' examples of their early experiences about STEM to show that each teacher could identify positive STEM experiences from their early years. Next, I present findings which explain teachers' understandings of STEM in ECE. I then present findings showing that teachers perceived potential STEM learning opportunities to be everywhere in their centres, and that teachers believed they could learn about STEM concepts together with children. Finally, I present findings which show that teachers value STEM, but that STEM is one of many learning areas in ECE for teachers to focus on.

Teachers' early STEM experiences

During focus group interviews, the teachers all provided positive examples of STEM from their childhood. For instance, Danielle talked about finding tadpoles and then watching them grow into frogs (Danielle/FG1). Although she focused on the science involved, her experience also involved other STEM areas. These areas included technology as she needed to design a habitat for the tadpoles to live in, engineering as she problem solved ways to catch the tadpoles, and mathematics as she watched the tadpoles grow, and made comparisons between them. Another teacher shared about the process of picking fruit from neighbourhood trees. Deborah and her friends "used different technologies" (Deborah/FG1) depending on the height of the fruit, problem solving, and using "more practical kind[s] of science and maths" such as tree climbing, throwing balls and using slingshots. Other teachers shared positive early STEM experiences such as exploring "different nature walks, in the bush" (Naomi/FG1), catching seafood, and preparing feed for cows.

Three commonalities were identified through analysis of the experiences that were shared. First, until they shared the experiences during the focus group interviews, the teachers had not thought of these times as involving STEM. However, on reflection they could identify and explain the STEM domains that were involved when they explained the experiences. Most teachers focused on the science and mathematics involved, with little mention of technology and engineering. Second, the teachers all shared their STEM related experiences positively, indicated by the excitement in their voices and laughter. Third, the experiences were all informal and practical, not involving any formal academic learning. The early experiences

indicated that the teachers held at a minimum, some positive early experiences about STEM, involving practical experiences, focused more on science and mathematics than on technology and engineering.

Teachers' understandings of STEM

This section presents findings about teachers' perceptions of STEM education in ECE. I begin with teachers' comments from the focus groups and individual interviews. I then present data from pedagogical documentation, and teaching and learning experiences recorded through participant observations.

The teachers at Charleston built their understandings of STEM during the research. At the first focus group interview, Naomi shared, "prior to your coming, the word STEM was new for us I would say. I know it's an acronym, but I wasn't aware of what STEM is." (Naomi/FG1). The other teachers reiterated this thought. The teaching team shared that they then investigated STEM, realising they had been teaching aspects of STEM, but not recognising or documenting it. Their realisation has consistencies with the literature about integrating STEM into existing curriculum, play and interests without requiring significant change in curriculum or teacher approaches (Bybee, 2013; MacDonald & Rafferty, 2015). The teachers at Piccadilly had more understanding about STEM when I first met with them. Similar to Charleston, the Piccadilly teachers acknowledged that they had been teaching STEM without recognising it:

> We might not use STEM like this is science, technology, but…a lot of our stories and our documentation is problem solving and taking challenges…And it doesn't directly cover science [and] technology, but it does about those skills which veers towards that [STEM]. (Deborah/FG1)

The teachers provided specific examples of STEM education such as in baking: "I feel like baking has science, maths and lots of STEM" (Sarah/FG1), construction with wooden blocks, and in experiences such as going for walks with children where interactions might focus on items like cracks in pavement, bees and letterboxes (Joanne/IN). In retrospect, the teachers could identify STEM in their teaching, but had not focused on it beforehand. As McClure (2013) noted, STEM was being learnt by the children, whether or not the teachers realised it. A change of teacher perspective could highlight the STEM related teaching and learning in the experiences, and lead to planning and teaching responses that are STEM related.

The teachers shared their views about STEM teaching and learning opportunities throughout the centre. For instance, during a focus group interview, Naomi shared the technological process involved in baking:

> First, they measure the ingredients, and then the mixing was there and then they put it in the shape, the tray and then they put it in the oven. (Naomi/FG1)

Other teachers also shared their thoughts about STEM involved in baking: “there’s all your STEM there with all the weighing and the measurements” (Danielle/FG1); “and how much to put in” (Naomi/FG1), “like the function of all those different equipments” (Georgia/FG1). The Charleston teachers provided further examples of STEM learning such as general weighing and measurement, floatation, investigating nature while gardening, making coloured icing, using an egg-beater, building with blocks—particularly when focusing on building a strong foundation—designing, and counting. Aligning with the nature of *Te Whāriki* as holistic, and the idea of STEM as being integrated (Lindeman et al., 2013), the teachers focused on integrated STEM rather than identifying specific domains.

The teachers also stated that they focused on STEM education in ECE as being more than just an outcome, but also being a process involving investigation and problem solving. At Charleston, a teacher noted: “in regards to STEM it’s that giving children a chance to investigate” (Danielle/IN). The teachers all shared children’s experiences they had seen where a process was used for investigation, such as when a child was working out if worms breath while involved in gardening (Naomi/IN), and when a child was investigating what happened to water in a sandpit (Georgia/FN). Like the Charleston teachers, the Piccadilly teachers focused on process when discussing STEM. At a focus group interview, Deborah said, “and the focus is not on the outcome as much as on the process” (Deborah/FG1). At the second focus group, Deborah again shared:

> STEM not necessarily it’s [not] just limited to the content…it’s more of a disposition, I think mainly it’s about the disposition, observation skills and problem solving skills. (Deborah/FG2)

Naomi reiterated her thinking:

> We want them [children] to be able to work out you know where, where, to trial and error. (Naomi/FG2)

Sarah added:

> It's all related to our philosophy (Sarah/FG2)

The teachers therefore had a firm belief that STEM education in ECE was about process and problem solving, reinforced by the philosophy statement of the centre: "Children have the right to learn the Skill and Habits of Mind that will prepare them for Life and Learning in the World of the 21st Century." (CD, 2017). While the teachers' views reflect Katz's (2010) view that STEM involves the three the aspects of process, outcome, and attitudes, the teachers focus was on process.

Data from pedagogical documentation and participant observations was consistent with the teachers' statements. Naomi shared a learning story (see chapter 2) she had written about a child who had built an animal farm using wooden blocks (CD/2017). Naomi had chosen to focus the documentation on aspects of creativity instead of STEM, but when prompted by me, could reflect on the learning to readily recognise the STEM domains:

> And all of it I could see STEM was there. She's like there's science, there's technology, there's engineering if you look at this animal farm…so maths is there, sorting, so she put the different animals in different places. Like so maths is involved there. The building itself is construction happening there, it's engineering. And the technology part of is how will the animals go down? How will they go up? (Naomi/IN)

An example of pedagogical documentation reflected the teachers' focus on areas related to, but not focused on STEM. Under the heading "transport", a wall display included children's different representations of real-world objects such as fire engines built using playdough, collage materials, and cardboard. The accompanying text was mainly descriptive, for instance, "[child] made his very own fire truck using collage and recycled boxes" with photos showing different stages of construction, various materials used, and multiple ways of joining the materials. Effectively, STEM teaching and learning was being documented and displayed in the photographs even though the domains or concepts of STEM were not explicitly identified.

Similarly, at Piccadilly, as children experimented with running onto and jumping from a foam wedge, a teacher observed and helped to manage the experience when required, but did not engage with the children about the STEM concepts involved. When viewing the video later, the teacher noted that the children were working out STEM concepts themselves, although they likely did not realise that they were engaged in STEM. The teacher explained that she did not engage in the cognitive aspects of the jumping with the children as she saw that they were

engaged in an experience that they had set up for themselves, and were wondering and problem solving together (Joanne/IN).

Pedagogical documentation focused mainly on problem-solving, social-emotional learning such as sharing, co-operating and peer learning, and on learning dispositions such as creativity, persistence and curiosity. Limited documentation emphasised science and mathematics, and no documentation was found that explicitly focused on engineering and technology. Yet, STEM related teaching and learning could be inferred in the documentation, and a small shift in the writer's lens could focus the documentation on STEM. For example, the animal farm story mentioned previously could focus on technological aspects of designing for purpose, and on engineering as an iterative process of building, testing and evaluating. The documentation could have noted the child's scientific classification of animals, including knowledge about the animals and their needs, and the mathematical concepts of geometry and shape involved in making the animal farm. As the teachers stated, STEM teaching and learning was occurring, but was not being recognised.

Analysis of the data showed that teaching and learning experiences related to STEM focused on science and mathematics more than on technology and engineering. Children's interests in themes such as space, leaves, and butterflies provided opportunities for teachers to engage in science and mathematics. For instance, during the celebration of Matariki (Māori new year), children and teachers engaged in teaching and learning about the constellation Pleiades, went on a visit to a planetarium, made their own constellations and discussed the shape of stars. Often, during everyday activities, teachers would introduce basic mathematical concepts such as size, number, shape and comparison, and scientific concepts. For example, when children did leaf rubbings, a teacher took the opportunity to engage in discussions about the function and make-up of the leaves. Following an interest in butterflies, the children worked directly with teachers to investigate the types and life-cycles of butterflies.

There were fewer episodes where teachers engaged in, or introduced engineering and technology into children's learning. Children's interests in baking provided the theme which led to the most technology teaching as teachers and children developed and followed recipes. Baking also provided opportunities for mathematics and science as the children and teachers counted, measured, and discussed the functions of some ingredients. In construction, at times the teachers became directly involved with the experience, voicing their thoughts and encouraging the children to think about engineering aspects of design, quantities, height, and

the properties of materials. An ongoing theme at Piccadilly was about building domino tracks with wooden blocks placed on their ends. Children built many tracks, problem solving and experimenting with spacing, and cause and effect. (I refer to this experience in chapter 4). Teachers at both centres were clear that it was easier to teach about the mathematical and science domains than the technology and engineering domains. The participant observations were therefore consistent with the teachers' statements about their perceptions of STEM, and with pedagogical documentation.

The teachers demonstrated an understanding of STEM education in ECE through their statements, and interactions with children. Pedagogical documentation hinted at the STEM domains, but did not focus on STEM. Overall, teachers had a stronger understanding of the science and mathematics domains, focusing on aspects of understanding the natural world, and mathematical concepts of counting, patterns and comparison. Teachers' understandings of technology and engineering were less defined. Most examples of technology focused on resources being tools for the children to use. Engineering was considered as the process of design and construction typically occurring with the wooden blocks.

As the next section shows, in keeping with the holistic approach to children's learning that is espoused in *Te Whāriki*, teachers perceived STEM as being integrated, rather than four discrete subjects. They also stated that STEM is embedded throughout *Te Whāriki* and throughout the centres.

It's everywhere!

"I just feel that STEM is just everywhere" (Sarah/FG1)

A common view held by teachers was that STEM learning occurs throughout everything the children are involved in. This view was apparent from the initial focus group meetings at both centres where teachers noted: "I found it [STEM] all integrated…I feel that we are doing STEM across the curriculum" (Sarah/ FG1), "I see it in all areas" (Danielle/FG1). Their thoughts were reinforced by general agreement amongst the other teachers during the interviews. When prompted to share examples of STEM being everywhere, teachers at Charleston identified areas such as the sandpit, in art activities, and in the construction area where children often used wooden blocks. Similarly, teachers at Piccadilly noted that opportunities for STEM learning were available through areas such as the sandpit, baking, and in wooden block construction. The teachers' view that STEM is everywhere continued throughout the data generation phase,

and was summed up at the final focus group meeting at Piccadilly: STEM "was actually just flowing in, in between all of what we do, [in the] day to day based experiences" (Naomi/FG2). STEM related teaching and learning opportunities were therefore viewed as being everywhere throughout the centre. Similar views were held about STEM education and *Te Whāriki.*

Teachers at both centres viewed STEM education as being embedded throughout *Te Whāriki*: "I think it [STEM] can be run right through it. Because it's a woven mat, that's what it is" (Danielle/FG1), "I feel quite natural [STEM integration], yea, that's how I found it all integrated, I found it quite natural" (Sarah/FG1). These views align with the non-prescriptive framework that *Te Whāriki* affords—that ECE is holistic, with many strands of learning woven together in planning and engaging in collaborative learning experiences.

During the second focus group interview at Piccadilly, Deborah raised an important point: "[STEM is] everywhere but you still have to breathe it…It still has to be made visible. If you don't access it, it's no point being everywhere." (Deborah/FG2). Deborah's statement points to there being many teaching and learning opportunities potentially related to STEM, but that these opportunities might not always be taken. Her statement was reinforced by the ability of the teachers to retrospectively recognise the STEM related teaching and learning that had occurred in many experiences, but that had not been focused on. Prompting the teachers to retrospectively look at the children's learning experiences may have highlighted for teachers that STEM was everywhere, but often overlooked. This perspective resonates with literature which points to missed opportunities, and is worthy of further research, but is outside the scope of this research.

Subject knowledge

As teachers' subject knowledge is entwined with teachers attitudes and perceptions in the prior literature, it was necessary to gain an overview of teachers' views on subject knowledge. This section presents findings about teachers perceptions of their STEM related subject knowledge, and how they overcame gaps in their knowledge by using ICT (information communication technology) and by drawing on the expertise of other teachers.

Teachers understood and embraced the fact that they did not have deep understanding of STEM concepts. For instance, during the first focus group meeting at Charleston, the teachers noted, "we don't have the answers" (Danielle/FG1), "we're not experts [in STEM]" (Nerida/FG1). Nerida recognised that not knowing could be positive adding, "a teacher not knowing is a

motivating feature [for the children]". She meant that when the children recognised that teachers did not know the answer to an inquiry, the children were then inspired to find out together with the teacher. Similarly at Piccadilly, Deborah embraced the fact that she was not an expert of everything related to STEM: "We don't have to be an expert…I love being a learner as well as a teacher" (Deborah/FG1). She then noted that it was more important to her to be able to find out information than to know it. At the second focus group interview, Naomi reiterated Deborah's thoughts "we aren't the experts…[but] finding out, that's what it's all about." (Naomi/FG2). The teachers were therefore clear that they were not experts in STEM, but that they did not view this negatively. Instead they shared ways of overcoming the gaps in their understandings.

To add to their own understandings, and to respond to children's inquiries, teachers used resources, most commonly ICT. At times teachers researched after the learning experience, as Georgia recounted: "I actually had to go online and search for things and then actually put it all together." (Georgia/IN). She then brought her enhanced understandings back to the children. At other times, the teachers researched in the moment with the children. For example, when investigating caterpillars' life cycles, and when investigating the shape of stars, the teacher searched for information on computer tablets together with the children. Georgia shared her views about the importance of learning together with children: "[It's] more meaningful for [the] children when the teacher sits down and says I don't know about this either. Let's find out together." (Georgia/IN). Georgia shared her views on subject knowledge when talking about an experience where she looked up information on the internet. She said, "so I had a bit of knowledge beforehand…I knew exactly what to search on the internet" (Georgia/IN). Similarly, Deborah shared how she and some children developed deeper understandings about how fish move through water from a child's inquiry about stingrays. Using the children's knowledge, Deborah then added prior theoretical knowledge gained from using ICT. Georgia's view, and Deborah's example have similarities to Krieg's (2010, 2011) argument that teachers should focus on the process of learning, and the outcome, and that they can be critical mediators. In these instances, the teachers started with the child's understandings and interests, then used ICT to identify prior theoretical knowledge to compare and contrast with it, and build deeper understandings.

My research did not seek to address how information communication technology (ICT) was used. However, a side note from data analysis was that information was usually presented without a critique of the source. One episode included an informal critique: in the star-shapes

episode which I detail in chapter 5, the teacher commented that the information she was reading was from the NASA website, “Nasa is the people who are like experts in the space so they know what they are talking about” (Georgia/VD). Further research on the use of ICT would be useful to investigate teacher’s critical use of it.

Teachers also drew on the strengths of each other when they felt they lacked subject knowledge: “I think that’s where perhaps the team has its role. Like there are certain aspect[s] of science and technology I may not know, but [other teachers] might be better off.” (Deborah/FG2). Similarly, at Piccadilly, Georgia shared that the teachers rely on each other in regards to STEM related subject knowledge (Georgia/FG1). Her view was confirmed by Danielle who noted that the teachers draw on each other’s expertise (Danielle/FG1). The teachers therefore felt that the strength of being a team was one way to overcome gaps in individual’s knowledge.

Overall, the teachers recognised that they did not have expertise in all areas related to STEM, and that therefore they had gaps in their subject knowledge. Teachers often built deeper understandings with children by beginning with the children’s inquiries and understandings, and adding prior theoretical knowledge to it. This theoretical knowledge was often gained by using ICT, and by drawing on each other’s expertise where necessary.

To see if the statements of the teachers were mirrored in their teaching, I decided to add another layer of analysis to the findings. The following section presents this layer, highlighting that while teachers did have positive perceptions towards STEM education, there were other areas of learning that were of higher focus.

Other learning areas

Consistent with literature, and the holistic nature of teaching in NZ ECE, the teachers identified that there are many learning areas for children to focus on. This meant that the STEM domains were one of many areas that children were learning about, and one of many learning areas for teachers to focus on.

Video data and pedagogical documentation showed that teachers focused on literacy and dispositions such as risk taking and curiosity more than on STEM. For instance, during the vignette *climbing frame,* which I describe in chapter 4, children were using a foam wedge to help them to reach an overhead bar. In a later interview, I shared footage of the vignette with the teacher who had been nearby. During the interview, she focused on the children’s ability to

cooperate and to make the experience a game with rules that they negotiated together, and on the disposition of courage that the children were showing (Joanna/IN). Her focus aligned with much of the overall data. There were many more instances of teachers supporting children to be creative and show positive dispositions towards their learning than engaging in STEM concepts. This focus was apparent in the children's learning story portfolios at Charleston. The introduction page of the portfolios stated: "The purpose of this portfolio is to make visible and to share learning that is valued" (CD/2017). The learning stories consistently highlighted literacy, learning dispositions such as curiosity, patience and perseverance, and areas such as friendship and behaviour indicating that these areas of learning were focused on more than STEM. These findings are consistent with the literature which notes that a priority on social-emotional learning (Kumtepe & Genc-Kumtepe, 2015; Simoncini & Lasen, 2018), literacy learning (Kumtepe and Genc-Kumtepe, 2015; French & Woodring, 2013), and dispositions (Hedges & Jones, 2012) mean that teachers might not become involved in or document STEM related learning.

STEM was everywhere, but often not the focus of the teachers. At Piccadilly, Naomi acknowledged that STEM related learning was occurring but not being documented: "STEM, science technology and all that, it is there, but like I said we were not documenting it" (Naomi/FG1). At times, STEM was mentioned in documentation, but backgrounded, such as in the Charleston planning notes:

> This has led to the children extending on their language skills (explaining to teachers and their peers on what they have created and also math concepts has been extended and developed as they learn about weight, balance and size during these building experiences). (CD/2017)

The animal farm learning story which is in chapter 2 mirrored this focus, as it highlighted a child's creativity while describing STEM related engagement. Again, STEM can be inferred in these interactions and experiences, yet was not the focus of the teachers. These examples indicate that STEM was indeed everywhere, but backgrounded by the teachers.

Analysis of the data also highlighted that the teachers relied on children's interests to create teaching and learning opportunities. For instance, at Charleston: "A lot of our things goes on with children's interests so that's where we always start." (Danielle/IN). Her thoughts were reinforced by the centre philosophy: "Extend children's interests and challenge their thinking in chosen areas of play" (CD/2017). Similarly, at Piccadilly the teachers focused on children's

interests: “that’s what we need to do, provide what they are interested in doing” (Joanne/IN). Again, her thoughts aligned with the centre philosophy: “daily activities are based around children’s interests” (CD/2017). Because children were often interested in topics and themes which involved STEM—for instance gardening and construction—this reliance did not necessarily constrain STEM related teaching and learning opportunities. However, because the interests were not always directly STEM-related, and because teachers mainly focused on literacy and dispositions within those interests, I argue that it further relegates STEM to a place of lower focus.

The findings mirror prior research which found that teaching and learning in ECE settings in NZ is a complex space. It should be expected that there are many learning areas, and that due to the play-based, holistic, non-prescribed nature of early childhood teaching and learning, there are many areas that are focused on. This section has explained the findings from this research which are consistent with the complexity of the early childhood teaching and learning space. In particular, I have highlighted that literacy and dispositions were predominantly a focus of teachers, and that a reliance on children’s interests to guide teaching, meant that the focus on STEM related teaching and learning was further reduced. I now move on to discuss the findings relating to the first research question.

Discussion

This section sets out to discuss the findings related to teachers’ perceptions of STEM education. As the findings have shown, the teachers in this research perceived STEM education positively. They all identified and related positive STEM experiences from their childhoods. The teachers could provide examples of STEM education in their centres, and could reflect on past experiences to identify the STEM related teaching and learning that occurred. The teachers perceived that STEM teaching and learning opportunities were available everywhere throughout their centres, and that STEM education was interwoven throughout *Te Whāriki*. The findings also show that there are other learning areas within ECE that teachers focused on more than STEM education. The focus on other areas indicates that while STEM education is perceived positively, teachers place a lower priority on STEM education than areas such as dispositions and literacy, and that a reliance on children’s interests compounds the lower priority that STEM education has.

The findings showed that teachers focused more on science and mathematics than on engineering and technology. These findings are consistent with the literature which highlights that teachers often fall back on the traditional domains of science and mathematics (Blackley & Howell, 2015). The findings are also consistent with *Te Whāriki* which highlights science and mathematics. The teachers' focus on science and mathematics could also be due to these being traditional school subjects, and perhaps domains that the teachers were more familiar with. However, that was not shown in the data, and could be the focus of further research.

In terms of STEM education, teachers noted that they focused more on processes and skills than on outcomes. As I noted in chapter 1, at worst-case, this focus could result in children becoming "self-confident fools" (Bruner, 1977. p. 65). A focus on the three aspects of STEM education that Katz (2010) argued—process, outcomes, and attitudes—would enable children to develop self-confidence that they have the skills to learn, to develop positive attitudes about the STEM domains, and to hold some subject knowledge. The combination of all three would then enable children to build on their existing knowledge, and to deepen and develop more complex understandings about the STEM domains. Krieg (2010, 2011) argued that process and outcome should be thought as being equally valid. Her thoughts that teachers could then compare and contrast children's understandings with larger theoretical understandings could enable children to work through a process of understanding, and simultaneously develop understandings. Therefore, children's learning would encompass both process and outcome. This notion could be the subject of further research in regards to STEM education in ECE.

Teachers' subject knowledge influences how a teacher might identify, engage in, and enrich potential teaching and learning opportunities (Kumtepe & Genc-Kumtepe, 2015). This thought is at odds with the thinking of the teachers in this research, who believed they could draw on other means—such as other teachers and using ICT—to overcome any gaps in their knowledge. It is important to note that the purpose of this research was not to ascertain the quality or breadth of teachers subject knowledge. The issue of teacher subject knowledge remains a contentious issue internationally, ripe for further research.

The findings showed that the teachers certainly did use ICT in many instances to learn about the STEM related concepts, and often with children. The concern remains however, that a lack of subject knowledge might limit the possible opportunities that a teacher can identify, and also limit the richness of their engagement in that opportunity (Kumtepe & Genc-Kumtepe, 2015). The ability of teachers to identify STEM related teaching and learning opportunities after the

event indicates that they did hold some subject knowledge which they could draw on. Again, Krieg's (2010, 2011) research can be drawn on here as a potential solution to the dilemma of subject knowledge for ECE teachers. She posited that teachers could act as critical mediators of children's learning. As I noted earlier, by critically mediating learning, Krieg meant that teachers could compare and contrast children's understandings with the greater theoretical knowledge about the topic or theme that is of interest. Some subject knowledge is still needed, however, teachers could then draw on that knowledge to gain further information to present, contrast, and compare with children's understandings. In this way, being a critical mediator aligns with the findings of this research, where the teachers embraced the fact that they were not experts on everything, and that children were inspired to learn when they discovered the teachers could not answer their queries. Teachers could then work together with children to wonder together about the children's understandings, to offer their tentative ideas, and then to research and learn together with the children. The issue of subject knowledge did not appear to affect teacher attitudes and confidence about STEM education, as I discuss next.

The teachers all expressed positive attitudes and confidence to engage in STEM related teaching and learning with their children. The positive recounting of early experiences involving STEM endorsed these views. These early experiences all involved practical, informal times, similar to the play-based ECE contexts of the research. In addition, the practical, informal nature of the experiences shared were consistent with the non-prescriptive philosophy of *Te Whāriki*. It is possible then, that the teachers' perspectives of their early STEM related experiences were influenced by the environments, contexts and philosophies in their teaching. Alternatively, their teaching philosophies, environmental setups and contexts could be influenced by their early experiences. More likely, it is a weaving of the two alternatives.

The view that STEM is everywhere aligns with the holistic nature of ECE in NZ and with *Te Whāriki*. As I noted in the findings section, the common view that STEM is everywhere is positive. However, as noted later in the data generation, it needs to be breathed. While STEM teaching and learning opportunities were potentially everywhere in both centres, factors such as demands for competing academic skills, a focus on dispositions (Hedges & Jones, 2012), and the long-standing discourse of relying on children's interests (Tippett & Milford, 2017) might have meant that there were many potentially missed STEM related teaching and learning opportunities. As I have explained, this research investigated teachers' and children's engagement in STEM related teaching and learning experiences. Research question 1

investigated teachers' perceptions of STEM, and therefore I did not focus on potential missed opportunities.

The teachers all shared positive early experiences related to STEM and could identify STEM related teaching and learning in children's experiences. The findings might then indicate that the teachers held positive attitudes, had good subject knowledge, and were confident to engage in STEM related teaching and learning. However, until this research, the teachers had not thought of their early experiences as involving STEM. Similarly, identifying STEM related teaching and learning normally occurred when I prompted the teachers to do so. Deeper analysis of the findings therefore showed that STEM education was not foremost in the teachers' minds, whether that be when thinking back about their early experiences, or while teaching. This was also evidenced in the pedagogical documentation which I explain next.

The pedagogical documentation hinted at STEM related concepts and learning, but consistently highlighted other learning areas such as creativity, and social skills. When prompted, teachers could identify the STEM learning that had occurred in the experiences that were documented. As highlighted in the findings, a small change in perspective could have enabled the documentation to emphasise STEM.

The episode where children were jumping from the foam wedge to the climbing bars (see chapter 4 for an explanation of this experience) provides an example which demonstrates the focus of the teachers. In this experience, there were many STEM related concepts that could have been identified, engaged with, and possibly enriched with the children. Concepts such as gravity, balance, speed, height, trial and error could have been identified. Instead, the teacher regarded her role as mainly supervisory because the children had come together to use the wedge without any teacher input, and were engaged in problem solving. By repositioning her focus, the teacher could have focused on the STEM domains (Bybee, 2013; MacDonald & Rafferty, 2015), potentially enriching children's understandings.

The focus on areas other than STEM education led me to reflect on the holistic nature of teaching and learning in ECE. The ECE teachers' role is varied and complex (Fleer, 2010) and certainly, a teacher cannot be expected to focus on everything at once. In fact, this is the very antithesis of focus. Through analysis of the findings, I identified areas other than STEM which were a higher focus for the teachers. First, a focus on literacy and dispositions indicated that these areas of learning held higher priority than STEM education. These findings are consistent with the literature which notes that a priority on literacy learning (French & Woodring, 2013;

Kumtepe and Genc-Kumtepe, 2015), and dispositions (Hedges & Jones, 2012) mean that teachers might not become involved in, or document STEM related learning. Second, a focus on children's interests might limit teaching and learning opportunities related to STEM (Tippett & Milford, 2017). This is because teachers believed that the children first had to show an interest in areas of learning that were related to STEM. Hence, children's interests could then constrain opportunities for teachers to engage in STEM related experiences. Teachers therefore held positive perceptions of STEM. However, the focus on other areas of learning, and a reliance on children's interests leading teaching and learning can be seen as constraining teacher engagement in potential STEM related teaching and learning opportunities.

Holding positive perceptions about STEM education in ECE, while prioritising STEM lower than other learning areas should not be seen as negative. Instead, the findings reflect the complexity of teaching in ECE in New Zealand. As I noted in chapter 1, *Te Whāriki* is a philosophical, non-prescriptive document recognising children as competent, capable, and confident. This view places an onus on teachers to recognise children as competent, capable, and confident, meaning that children are often viewed as the initiators and authors of their own learning. Furthermore, as a non-prescriptive document focusing on children and their learning as being holistic, *Te Whāriki* does not state that teachers must focus on learning areas such as STEM per se, or prescribe specified academic knowledge related to STEM that children must learn. Instead, curriculum topics and foci are seen as a place of negotiation between children, their families and teachers. In addition, as I described in chapter 2, both ECE settings in this research operated under philosophies of play-based learning where children were free to choose the activities and experiences that they wanted to be involved in. Together, the nature of *Te Whāriki* and the philosophies of the ECE centres mean that teaching and learning will be dynamic, flexible and negotiated spaces. Teachers are likely to focus on many learning areas, and hold positive perceptions about those areas, including STEM, as seen in this research.

Conclusion

As the teachers in this study reported, STEM is everywhere. Perhaps the same could be said of many other learning areas in ECE, reflecting the complex teaching and learning contexts that ECE centres provide. Even if STEM education is perceived positively, it cannot be expected to always be at the forefront of an ECE teacher's mind. Curriculum is a negotiation between children, teachers, and families, and there are not specified periods of each day that are set aside for STEM. Teachers are busy and fulfil many roles. In addition, there are many learning

areas to focus on. Therefore, many potential STEM related teaching and learning opportunities will not be taken. This is not a judgement of the centres or the teachers at all. Instead it reflects the complex role of an ECE teacher.

This chapter has addressed research question 1: How do teachers perceive the place of STEM education within ECE? In short, teachers perceived STEM positively, and as being everywhere throughout their centres, and as being woven throughout *Te Whāriki*. Teachers viewed STEM education as important for children's learning, and viewed themselves as being confident to engage in teaching STEM. Teachers perceived that while they could not hold deep subject knowledge about all STEM related concepts, that they could use resources—in particular ICT—to learn about those concepts.

Teachers could identify and engage in science and mathematics teaching more readily than in technology and engineering, most likely due to their educational backgrounds. Teachers could identify STEM when prompted to when re-viewing learning moments. Little pedagogical documentation was found that identified the STEM learning that children were involved in, indicating that teachers placed higher priorities on other areas of learning. Observational data reiterated that other areas of learning such as literacy and children's learning dispositions were viewed as having higher priority than STEM education. The holistic nature of *Te Whāriki* means that the idea of focusing on STEM could be viewed as problematic, as holism and focus could be seen as dualistic.

However, perhaps an even greater holistic view of learning could encompass STEM more fully into everyday teaching and learning while still including other areas viewed as important by teachers. Re-focusing teaching and learning to encompass all areas of learning might enable STEM to be seen in any learning experience. This re-focus would mirror the ways that young children approach learning—not generally seeking to find out about an individual area, but seeking to learn about the world and their place in it. Yet, this perspective too is likely problematic. Teaching and learning can be a delicate affair. A wider focus might result in no focus. Just as STEM is everywhere, learning might be everywhere, leading to a lessening of the teacher's role and a preponderance for children to learn through osmosis.

While this thesis does not intend to resolve the broader philosophical aspects of teaching and learning, I argue that STEM education holds a valid place in ECE. As the world increasingly becomes understood as a series of highly complex interconnected systems, STEM education in ECE is critical. It provides young children with knowledge, skills, and attitudes that they can

draw on through their life, and which can inspire further interest, investigation and understanding of the world.

Through this research, I have found that teachers hold positive perceptions of STEM in ECE contexts, but that those contexts are complex and challenging with other learning areas that teachers must choose between. The positive perceptions towards STEM education in ECE provides a basis and confidence to proceed with investigating working theories about the STEM domains. The next chapter—chapter 4—focuses on children's development of working theories about the STEM domains.

4. Working theory development

"Learning at its most general is the business of improving our theories, elaborating and tuning them" (Claxton, 1990, p. 23).

Introduction

Working theories are tentative and evolving ideas and understandings that young children generate and refine to make sense of the world (MOE, 2017). They are an important part of ECE, being one of two notions—alongside dispositions—that knowledge, skills, and attitudes are described as combining to form in the early childhood curriculum document *Te Whāriki* (MOE, 2017). This chapter builds on prior research about working theories, and presents findings from this present project's research to focus on the development and enrichment of working theories. Consistent with chapters 3 and 5, this chapter includes a rationale for investigating working theories. I then critically review literature related to working theories, then build on prior research to present working theories as being three-fold—process, outcome, and interpretive framework. From this perspective, I build to a spiral of working theory development model by drawing on Dewey's (1910) spiral of knowledge, and Wells' (1999) spiral of knowing. I next present findings from this research using the spiral of working theory development model as a framework, then discuss those findings. A further theoretical layer is added to the findings in chapter 6.

In this chapter, I present the spiral of working theory development model which is both an analytical framework and outcome of this research (see chapter 2 for an explanation about the development of the model). The model is an original and innovative way to view working theory development, adding to existing understandings about working theories. As I argued in chapter 1, working theories have worldwide significance due to the growing research and literature base both in New Zealand and internationally. In addition, working theories have potential similarities to other related notions such as thinking, concept development and knowledge building. The findings of this chapter, and the model that I present therefore have global relevance.

Rationale

Working theories are an important outcome of ECE in New Zealand. As noted in chapter 1, they are positioned twice in *Te Whāriki* (MOE, 2017). First, they are described as one way that

knowledge, skills, and attitudes combine. Second, they are one of the 20 learning outcomes of the curriculum. According to the original version of *Te Whāriki* (MOE, 1996), working theories afford children with knowledge, skills, strategies, attitudes and expectations which lead to ongoing and developing understandings of their world, an understanding and sense of power over their lives, positive attitudes towards learning and abilities to solve problems. Working theories are therefore an essential aspect of ECE. They are a significant part of the ECE curriculum, and an important part of a child's life. Research into both the notion of working theories, and how to support working theory development is therefore essential to provide understanding of, and engagement in the concept (Hedges, 2014).

This chapter is the result of drawing recursively on literature and findings to develop and refine a unique and innovative model called the spiral of working theory development. This model represents one way that children might develop and refine their working theories about the STEM domains. Offering a model for the development of working theories is highly important. Breaking down and understanding the process will enable a deeper understanding of working theories, providing understandings on which to develop teaching approaches, and offering a basis for further research about working theories. As I argued in chapter 1, working theories are also related to similar notions which are recognised internationally such as thinking, concept development and knowledge building. A deeper understanding of working theories and their development has implications for these notions.

A greater understanding of how working theories are generated and refined could also lead to more authentic and responsive teaching approaches than teachers currently use to foster children's working theories. I address teaching approaches in chapter 5.

Literature review

This section presents a critical review of literature related to working theories. To begin with, I overview literature about the notion of working theories, and prior working theory research. Next, I define working theories for this research, before reviewing the literature that led to the development of the spiral of working theories development model.

Working theories in *Te Whāriki*

The term working theories was first presented in the draft version of the early childhood curriculum framework *Te Whāriki* (MOE, 1993). Working theories were noted as being based

on Claxton's (1990) notion of minitheories: a "large number of purpose-built, situation-specific packages" (p. 66) that people edit and apply as they engage in experiences to make sense of their world. In 1996, the original version of *Te Whāriki* (MOE, 1996) was released. In this version, working theories were positioned as one of two overarching holistic learning outcomes (alongside dispositions), and as 1 of 117 specific learning outcomes. In *Te Whāriki,* the notion of working theories was not specifically defined. Instead a description was provided as a combination of knowledge, skills, attitudes, strategies and expectations. Working theories were also described in terms of their usefulness and development. First, as becoming more elaborate through experiences, knowledge and skills, and as becoming connected and more widely applicable and useful for children to make sense of their world. Second, as developing through "observing, listening, doing, participating, discussing and representing" (MOE, 1996, p. 44).

In the 2017 version of *Te Whāriki* (MOE, 2017), working theories were described as one way to view the combination of knowledge, skills and attitudes. This time, a definition was provided: "*Working theories* are the evolving ideas and understandings that children develop as they use their existing knowledge to try to make sense of new experiences" (p. 23). Similar to the original curriculum version, development of working theories was linked to experience and knowledge: "As they gain experience and knowledge, children's working theories become more connected, applicable and useful and, at times, more creative and imaginative." (p. 23). In addition, working theories was included as one of the 20 learning outcomes of *Te Whāriki*, located under the exploration strand: "over time and with guidance and encouragement, children become increasingly capable of…[m]aking sense of their worlds by generating and refining working theories" (p 47). Clearly then, working theories are viewed as a key component of ECE in New Zealand. Research about working theories began in the mid-2000s. In the next section, I describe the ongoing research to date.

Prior research

Through the benefit of hindsight, it can be seen that working theories were introduced to the early childhood community as an imprecise, complex and multi-faceted concept, difficult for teachers to grasp. Little research or professional development was undertaken about working theories until the mid-2000s, leaving the concept as potentially nebulous and therefore likely disregarded by teachers (Hedges, 2011). Since the mid-2000s, momentum in working theories research has been building. This section reviews the research beginning with the large-scale projects, moving to postgraduate research and finishing with small-scale research.

Four large research projects have been undertaken in New Zealand which I explain later in this section (Davis & McKenzie, 2017; Davis & Peters, 2011; Haworth et al., 2006; Hedges & Cooper, 2014a). Furthermore, postgraduate studies have been undertaken investigating working theories in New Zealand (Hargraves, 2011; Kelly-Ware, 2018; Lovatt, 2013), and a further postgraduate study in England (Hill, 2015). Finally, two small-scale projects have been undertaken (Kelly et al., 2013; Sands, Carr, & Lee, 2012). I explain these research projects next.

The first large working theory research project began as part of a larger study investigating improvement of teaching and learning at a kindergarten (Haworth et al., 2006). The final report highlighted teachers' working theories about ways to support children's learning, rather than how children develop working theories per se. A few years later, children's working theories became the focus of a second large research project.

Davis and Peters led the second large research project focused on children's working theories (Davis & Peters, 2011). Their research investigated the development of children's working theories in adult-led playcentres. Key findings were that working theories provide a rich space for deep and complex learning; teachers face dilemmas when fostering working theory development; and identified that ways teachers interact with children can foster working theory development. This research has important implications for my study in that the researchers drew on Claxton's (1990) analogy of islands of expertise to describe the development of working theories. In short, this analogy holds that people have many islands of knowledge. New experiences can place them on firm ground if they can relate the new information to what they already know, or place them at sea, unsure how to relate the new information to their island of knowledge. The islands can grow, interconnect and subsume one another as new information expands the knowledge, and therefore the size of the island. Experiences, information and knowledge are key aspects of the analogy, and are also key aspects of the spiral of working theory development model as I explain later in this chapter. Momentum in working theories research was building, and soon the next large research project on working theories took place.

The third large research project focusing on working theories investigated the nature of children's working theories, and ways teachers noticed, recognised and responded to working theories at two ECE centres (Hedges & Cooper, 2014a). Their first research question corresponds with this chapter: What is the nature and content of infants', toddlers', and young

children's inquiries and working theories in relation to their everyday lives in their families, communities, and cultures? I outline the second research question in chapter 5. In terms of developing working theories, the research noted the importance of children's interests. It highlighted that deep interests were a key motivator to developing working theories and that life experiences influence children's working theories. The premise that experiences are a key aspect of working theory development is a key factor in my research as I explain further in this chapter. To understand children's interests, the researchers used a funds of knowledge approach (González, Moll, & Amanti, 2005), primarily using dialogue with children and their families and visits to the family homes. I discuss this research further in chapter 5 which focuses on teaching approaches.

More recently, Davis and McKenzie built on Davis and Peter's earlier work (2011) by investigating working theories about culture and identity in two early childhood centres (Davis & McKenzie, 2017). They noted that children's working theories were related to making sense of the world, and that lived experiences provided powerful knowledge which children used to make sense of new experiences, then developing new working theories. Again, and of significance to my study, experience was a significant aspect of working theory development. While these large-scale research projects have been undertaken there have also been smaller-scale projects which I discuss in regards to the development of working theories next.

As already noted, four postgraduate studies have also been undertaken to investigate children's working theories. These include Hargraves' (2011) practitioner research investigation into teachers' support of working theories; my practitioner research investigating ways that teachers might invoke disequilibrium in children's working theories Lovatt (2013); and Kelly-Ware's (2018) research which investigated fairness and diversity using a working theory lens. The fourth postgraduate study was undertaken outside of New Zealand by Hill (2015). She undertook postgraduate study in England to investigate how young children develop and use working theories in play-based contexts. Hill found that children developed working theories related to human nature, the social world, and the physical and natural world, and proposed that they might be a means for children to develop ethical, social and gender identities. Hill also noted that focusing on working theories might provide an alternative to nationally directed goals and outcome based learning for young children by enabling teachers to create local, responsive curriculum. Key findings from these postgraduate studies which relate to this research were that working theories become elaborated and interconnected from experiences with people, places and things (Hargraves, 2011; Lovatt, 2013); working theories involve

fitting new information into existing knowledge outside of the context they were first experienced in (Hargraves, 2013); and working theories develop in non-linear ways (Lovatt 2014; Hargraves, 2013). In addition, two small-scale research projects focusing on working theories have been undertaken which I discuss next.

Two small-scale studies focusing on working theories have been located. Sands et al. (2012) explored how a question asking and question exploring culture helped the development of working theories. The actual process of developing working theories was not investigated, however the importance of children testing and then re-testing their ideas to deepen understandings was noted. This iterative process is consistent with the spiral of working theory development model as I describe later in this chapter. A project researching pedagogy related to sustainability and the environment involved a kindergarten focusing on the question "How do children express their working theories after regular engagement with nature outside the gate?" (Kelly et al., 2013). The research found that children generated complex working theories that teachers were not always aware of, and that teachers often made assumptions about the children's interests and therefore disrupted the further development of working theories.

Multiple articles and chapters have been published from the aforementioned research. In particular, Hedges has continued to disseminate literature in international journals about working theories. Her work has produced key findings of relevance to this project, including that working theories come from everyday experiences of the real and social world (Hedges, 2008); working theories develop as children make connections between prior and new experiences and understandings (Hedges, 2012, 2015; Hedges & Cullen, 2012); working theories develop when a concept is used in a different context (Hedges, 2012); and that working theories are a way for children to "connect, edit, extend and deal with new or discrepant pieces of knowledge in order to build their understandings" (Hedges, 2014, p. 35). Working theories were also offered as a lens to view and analyse the complex issues of content, coherence and control in regards to ECE curriculum (Wood & Hedges, 2016). In addition, Wood and Hedges offered working theories as a potential solution to the growing demand for a focus on academic outcomes in ECE. Instead, they positioned working theories as holistic and as a notion—together with children's interests—that teachers could focus on to responsively and creatively build curriculum. There are issues and challenges, such as teacher subject knowledge, inherent with the approach they espouse, and which I discuss in chapter 5. Peters and Davis have also published internationally about their ongoing working theory research (Peters & Davis, 2011,

2015, Peters, Davis, & McKenzie, 2018). Furthermore, Areljung and Kelly-Ware (2017) have published their joint international research about teacher power and control over working theories.

In addition, a search for international literature about working theories located research undertaken in Luxembourg about young children's exploration of science (Siry & Max, 2013). The research used the terms working theories and working ideas interchangeably without defining either term. Both terms appear to have an alignment with the New Zealand concept of working theories as they were about the development of evolving understandings. This research found that a curriculum based on children's interests and motivations could lead to the development of children's working theories. There is now a foundation of research and literature about working theories to build on, yet there is much yet to be explored.

STEM per se has not been the focus of prior working theory studies. Instead, the studies have reported on diverse findings related to friendship (Hedges & Cooper, 2014), science (Davis & Peters, 2011; Hargraves, 2011; Hedges & Cooper, 2014; Lovatt, 2013), engineering (Hargraves, 2011), diversity (Davis & McKenzie, 2017; Kelly-Ware, 2016), and culture and identity (Haworth et al., 2006; Davis & McKenzie, 2017). No findings related to technology or mathematics have been located. In addition, no research has been located exploring working theories about the four integrated STEM domains. My research therefore adds to the growing diversity of working theory research by focusing on working theories related to the STEM domains.

As I have explained, the prior studies found that the notion of working theories is complex, and that children develop working theories through experiences, in non-linear ways, and elaborate and enrich them over time. A closer focus on how working theories are developed will lead to a deeper understanding of the notion, offer insights into ways that children go about forming working theories that in turn could provide deeper understandings on which to base teaching approaches, the topic of the next chapter. Therefore, the research question that this chapter addresses is: How might young children develop working theories related to the STEM domains?

Working theories for this study

It is important to define and explain my understanding and use of working theories in this research, which I do in this section. I then draw together understandings of working theories

from prior literature to present working theories as process, outcome, and interpretive framework. Next, I introduce and explain the notion of knowledge building (Scardamalia & Bereiter, 2003; Wells, 1999) which I weave together with the three-fold view of working theories as process, outcome, and interpretive framework to present the spiral of working theories development. As I explained in chapter 2, the initial model was developed from the initial literature review, and was subsequently recursively revised during data analysis. The model therefore presents an interweaving of findings, theory, and literature, used as a framework to analyse the findings, and modified by the findings. I present the model later in this chapter.

In chapter 1, I defined working theories for this research as the following:

"Working theories are the tentative, evolving ideas and understandings that children develop as they use their existing knowledge…" (MOE, 2017, p. 23) and understandings to make sense of new information. Working theories act as interpretive frameworks of information gained from further experiences and are therefore the skills used to process the new information.

This definition draws on my conceptual framework which I also described in chapter 1. To recap, my conceptual framework brings together sociocultural and social constructivist theoretical perspectives within an interpretivist paradigm. In terms of working theories, an interpretivist paradigm means that young children develop working theories to make sense of the world as they know it. Working theories are necessarily different for each child as they all have experienced the world differently and hence interpret it differently.

A social constructivist perspective views working theory development as being influenced by others—social—but generated by individuals—constructivist. From a social constructivist perspective, working theories are generated through social interaction in some form, for instance, as children learn and discuss together. However, because a social constructivist perspective means that knowledge is built through experience, and because every child has had different experiences, every working theory must therefore be unique in some way. A sociocultural perspective means that working theories are formed in, and influenced by, social and cultural settings. As I explain further in chapter 5, this perspective means that teachers' approaches can be considered as both direct—for example, direct interactions with children—and indirect—for example, the general setup that the environment provided by teachers affords.

In short, my conceptual framework leads to a perspective that children form working theories to interpret their world. Working theory development occurs in the mind of the individual, but is highly influenced by other people, the social world and the cultural context within which the children are learning.

Up to this point, I have described working theories through the perspective of my conceptual framework and explained working theories as being a combination of knowledge, skills, and attitudes. In the next section, I explain working theories again as three-fold, but this time as process, outcome, and interpretive framework.

I consider working theories as involving three aspects. I depict this in Figure 7 below.

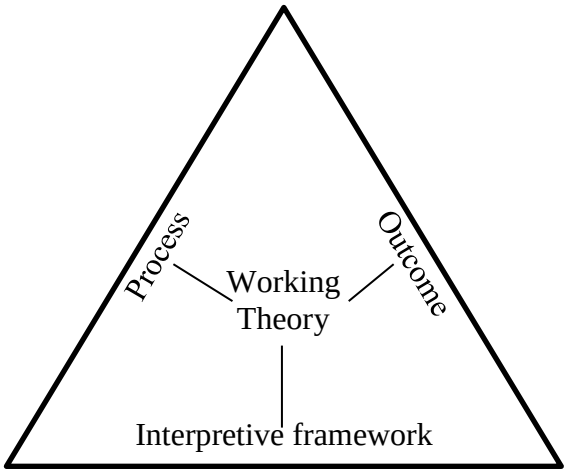


Figure 7. A three-fold view of working theories.

Working theories are a process, outcome, and an interpretive framework for processing further working theories. This is an innovative perspective which builds on and brings together prior literature about working theories as I describe next. The first two aspects have been identified in prior literature. Sands et al. (2012) noted that working theories involve both knowledge and knowing. Their views align with Davis and Peters (2011) who described working theories as both interdependent noun and verb—an inseparable and overlapping combination of action and object. Similarly, Wells (2000) noted that theory building involves similar aspects of forming understandings and the understanding itself. Furthermore, in *Te Whāriki* (MOE, 2017) working theories are presented as a combination of knowledge, skills, and attitudes, and the previous version (MOE, 1996) includes strategies and expectations. Hence, again working theories are both noun and verb, or process and the outcome. By the action or process of forming a working

theory, children concurrently construct a working theory as an entity or object in the mind. The third aspect of working theories is as interpretive frameworks. In *Te Whāriki,* working theories are seen to evolve as children use "existing knowledge to make sense of new experiences" (MOE, 2017, p. 23), aligning with Hedges and Jones' (2012) statement that working theories are "a framework for making sense of new experiences and ideas" (p. 36). In this regard, working theories are transformative and historic intersections. They are new constructions of the past, as experiences and information are filtered through an existing, but evolving interpretive framework. They are a way of making sense of the past by constructing working theories based on past and present (which are then necessarily past) experiences and information. Working theories then project into the future by providing an enriched framework for viewing new experiences, new information, and thus for constructing new working theories. I argue that this three-fold perspective of working theories locates working theories as mediators which I explain in chapter 6. The three-fold perspective of working theories is an essential underpinning of the spiral of working theories development model which draws on the concept of knowledge building. I discuss this concept next.

I now move to focus on the concept of knowledge building which I draw on together with the three-fold understanding of working theories to present the spiral of working theory development. As I have argued in chapter 1, working theories have relevance internationally as they have similarities with notions such as thinking, concept development and knowledge building. The notions of thinking and concept development are outside the scope of this research. However, knowledge building is a notion that I have drawn on as a basis of the spiral of working theories development model. Therefore, I explain knowledge building for this research next.

Knowledge building is a concept that is relevant to working theories as it forms the basis of the spiral of knowing (Wells, 1999), a model which is central to the spiral of working theory development model. Knowledge building has been primarily developed by three key authors: Wells (e.g., Wells, 1999, 2008), Scardamalia and Bereiter (e.g., Scardamalia & Bereiter, 2003, 2006). Knowledge building foregrounds conceptual entities, ideas and theories:

> Knowledge building may be defined as the production and continual improvement of ideas of value to a community, through means that increase the likelihood that what the community accomplishes will be greater than the sum of individual contributions and part of broader cultural efforts. (Scardamalia & Bereiter, 2003, p. 1370)

To model knowledge building, Wells (1999) adapted Dewey's (1910) spiral movement of knowledge, to form the spiral of knowing (Wells, 1999). Wells' spiral incorporates four elements: understanding, experience, information, and knowledge building, and is the basis for the spiral of working theory development model which is explained later in this chapter. As I argued in chapter 1, knowledge building is similar but not interchangeable with working theories, presenting a different perspective of knowledge, skills, and attitudes. Granted, one facet of working theories is knowledge, however as I have argued, working theories also encompass a much wider view of learning, including, skills, attitudes, process, outcome, and interpretive framework.

In the next section, I present and explain the spiral of working theory development model. As I have explained in chapter 2, this model was developed near the beginning of the research process during the literature review phase, and was refined as data was generated and analysed. Later in this chapter, I use the spiral of working theory development to frame and present the findings. The spiral of working theories model draws on my previously described understanding of working theories as three-fold: consisting of process, outcome, and as being an interpretive framework. The model combines the following ideas explicated more fully shortly: the original and underpinning notion of working theories: minitheories (Claxton, 1990); Dewey's (1910) notion of the spiral of knowledge; and Wells' (1999) notion of the spiral of knowing. In essence, the spiral of working theories involves "elaborating and tuning" (Claxton, 1990, p. 23) understanding and ideas through four elements, that is through experiences, information, making connections and enriching understandings. Of importance to the model is Wells (2002) statement: "there would be general agreement that knowledge is constructed by individuals through an active relating of new information to their personal experience and their current frameworks for making sense of that experience" (p. 2).

The spiral of working theory development model

Past research on working theory development has highlighted the importance of experiences for young children. The importance of experience resonates with Wells' (1999) spiral of knowing model. However, before I move to his spiral, it is important to consider how experience influences working theory development. First, working theories are tentative and evolving hypotheses of the world as the children know it. Second, working theories are based on the evidence available to the children, generally gained from experiences undertaken or engaged in. Third, working theories develop due to the effect of the new evidence on the

hypotheses already held. Therefore, working theories can be viewed as developing hypotheses about how the world works, based on evidence provided from experiences. The process is not close to being linear or straightforward, but instead is dynamic and complex. However, the development could be viewed in "a dynamic and spiral fashion" (Lovatt & Hedges, 2015, p. 911).

Building on this viewpoint of working theories, and relating it to Wells' (1999) model, I argue that the enrichment and elaboration of working theories can be viewed as a spiral. The notion of a spiral movement of knowledge was first proposed by Dewey (1910). A spiral movement of knowledge is a process whereby existing knowledge is used to interpret new "subject matter" (p, 120) which then leads to new knowledge. This process repeats: the new knowledge is used to interpret further subject matter, and again, new knowledge is formed. Dewey viewed this as a continuous spiral movement. His notion was developed further by Wells (1999) as a spiral of knowing incorporating four elements: understanding, experience, information, and knowledge building, applicable to both individuals and groups of learners. According to Wells, in the spiral of knowing, a learner starts with interpreted past experiences, then engages in new experiences which provide new information. The learner engages in knowledge building as a responsive attempt to make sense of the new information and experiences, resulting in deepened or new understandings. These understandings then become the starting point for the next iteration of the spiral.

The spiral of knowing presents a model to potentially understand the development of working theories. The three aspects of working theories—knowledge, skills, and attitudes—and from the original version of *Te Whāriki* —the aspects of strategies and expectations—can be related to each element of the spiral of knowing. The elements of experience and information do not simply refer to exposure to an experience or information. Rather they are the deeper meanings that individuals and groups construct through the experiences undertaken and information gained (Wells, 1999). Skills, strategies, attitudes and expectations could be considered as aspects of forming meaning. First, a child might have an experience or notice information while holding an attitude of curiosity. The attitude of curiosity interweaves with an expectation to see something new and exciting, leading to a desire to explore. Second, skills and strategies are required to make meaning of the experience and information. Without these skills, strategies, attitudes, and expectations, the experience and information would be largely meaningless. The final element—understanding—can be related to the working theories aspect of knowledge in relation to new understandings formed, and new knowledge gained.

However, anomalies between the spiral of knowing and working theory development prompted me to use the spiral of knowing as a starting point for the model I call the spiral of working theory development. Wells originally developed the spiral of knowing within a community of inquiry, focusing on collaboratively inquiring and building knowledge. His model has relevance for ECE contexts where children inquire and learn collaboratively through everyday experiences and activities. The main concern with the applicability of the spiral of knowing to working theory development centres around two points. First, although this might be pedantic, rather than beginning the spiral with past interpreted experiences, the spiral of working theory development begins with the existing understandings that a young child brings with them. Second, the element of knowledge building focuses on progressively improving representational artefacts, undertaken with systematicity, coherence, consistency, with presentation to others (Wells, 1999). This does not represent the dynamic, complex and informal teaching and learning moments that were found in the settings in this research. In addition, the nature of knowledge being an "improvable object" (Wells, 1999, 2000, 2002, 2008) could lead to an emphasis on conceptual accuracy which does not align with *Te Whāriki* or the findings. At times, working theories might be enriched and elaborated, but not improved with conceptual accuracy, as the castle vignette demonstrates (see the findings section of this chapter). Finally, Wells describes knowledge building as a recursive process that can take place within one cycle of the spiral, indicating that one iteration of the spiral represents one classroom lesson. Again, this thinking does not align with the informal nature of ECE teaching and learning. In the spiral of working theories, multiple iterations of the spiral will likely occur during the formation of working theories. Through each iteration, the working theories become very slightly elaborated, and enriched, and sometimes they might even become more conceptually accurate. For instance, every time a young child pours water from one container to another they might be enriching and elaborating their working theories about the nature of water, weight, quantity, and conservation of quantity. They might pour between the containers many times. Therefore, this research takes the spiral of knowing and builds on it as I describe next.

The spiral of working theory development model then incorporates subtle but significant modifications to Wells' (1999) model. The major change is in the view of children's conceptual accuracy. Rather than iterations of the spiral leading to improvement of knowledge, I consider iterations lead to an enrichment, elaboration or broadening of working theories. At times, reflecting the nature of young children's learning, their working theories might become less

conceptually accurate and even fanciful. However, remembering the three-fold nature of working theories as process, outcome, and interpretive framework, I contend that this still enriches, elaborates and broadens their working theories, which is a creative and critical aspect of learning such as creative and complex thinking. This view prompted me to reflect on the element of knowledge building, which I have re-conceptualised as making connections. This term draws on Claxton's (1990) original theoretical basis of working theories: minitheories. Claxton argued that minitheories are purpose-built situation specific packages that combine as knowledge, and interpret new information. He argued that children engage in gradual editing of minitheories so they become more useful, effective, comprehensive, appropriate, and connected over time. In this context, I view making connections as a transformative period where, as the title suggests, connections are being formed between already held understandings, and new information. As depicted in Figure 7, working theories function as interpretive frameworks which are used to filter and make sense of new information to form new understandings. Importantly, the individual cannot be separated from the social and cultural setting at this time. Whether it is the result of conversation, engagement or interactions, making connections is influenced by the environment, context and situation that the children are in.

The final modification was to locate working theories as encompassing all four elements of the spiral of working theory development. As already argued, engagement in experiences, leading to recognition of new information, making connections and forming new understandings lead to the development of working theories. The spiral of working theory development model is presented in Figure 8.

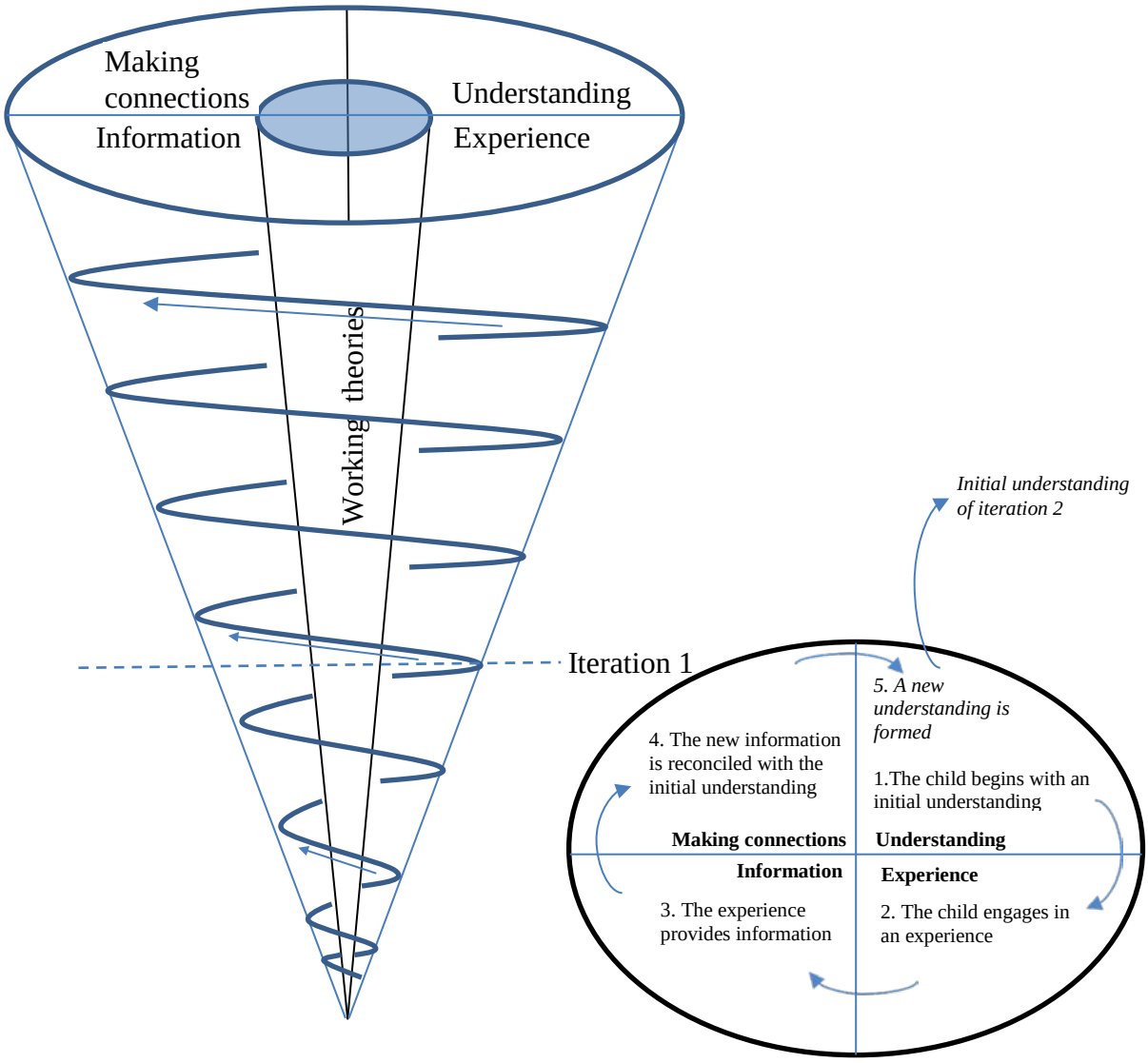


Figure 8. The spiral of working theory development.

In short, a learner holds existing understandings, then encounters new experiences which provide additional and sometimes discrete information. Connections are made between the new information and existing understandings as a responsive attempt to make sense, resulting in enriched or new understandings. Together, the four elements of the model combine to make up working theories. These working theories form the starting point for the spiral to repeat from the understanding element. Hence, the model is a cone shape, depicting that the working theories become broader through iteration. Furthermore, the deepened or new working theories serve as an interpretational framework to filter new experiences and information and thus to form further new or deepened working theories.

The shaded centre of the spiral denotes the working theories of the children. This space can be visualised as a place of possibilities. An interpretivist and social constructivist view of learning

means that this space is different for every child. Much information is available from any experience, and each individual will gain different information. Each individual then connects the information that they take from the experience to past understandings that they hold. New connections are formed, new understandings result, and new or refined working theories are formed.

Development of working theories is not a linear, predictive process resulting in progressive understandings. As the castle construction vignette shows in the findings section, sometimes an iteration around the spiral will result in what might be deemed steps towards conceptual accuracy, and sometimes steps away from conceptual accuracy. Nevertheless, as further information is gained, and connections are made, the working theories are elaborated and deepened as indicated by the widening of the shaded centre.

It is important to clarify that understandings on their own are not working theories. I have already argued that working theories are three-fold: process, outcome, and interpretive framework. Therefore, working theories are not simply an entity in the mind. They are the result of experiences, information, mental action—that is making connections between new information and existing understandings—and new understandings. This might explain why some working theories are difficult to shift. For instance, Peters et al. (2018) shared an example of a child who had a working theory about how to open a coconut. His method involved sawing the coconut with a knife, which did not work. However, the child maintained his working theory even though alternative theories were offered, and demonstrations of alternative ways to open a coconut were viewed by watching videos. His mother later shared that the child often cut vegetables and fish using his method. The importance of the home experiences and the people involved that led to the child's working theory might have outweighed the importance and validity of the new evidence gained from the ECE centre. Recognition of working theories as including all four elements of the spiral of working theory development could then lead to new understandings about the influences on working theories and lead to new teaching approaches.

I now use the spiral of working theory development model to present the findings from this research that address research question 2: How might young children develop working theories related to the STEM domains? As I have explained in the methodology chapter (chapter 2), there was a recursive process involved between literature and findings which lead to the final iteration of the model.

Findings

This section presents findings addressing research question 2. I first present examples of findings from both centres about working theories relating to the STEM domains. These are broader overviews intended to demonstrate the breadth of data obtained. Next, I present two vignettes in-depth to highlight the development of working theories related to the STEM domains. These two vignettes illustrate the three-fold nature of working theories as process, outcome, and interpretive framework, and the application of the spiral of working theories development model. Both vignettes involve working theories about the integrated STEM domains (other domains such as social and emotional are acknowledged, but are outside the scope of this thesis) and involve problem solving, first about using materials to aid with construction, and second in attempting to reach the overhead bar of a climbing frame.

Table 3 provides examples of STEM related working theories from my study. Decision making about which data to use was difficult and is described in the data analysis section of chapter 2. Due to the space constraints of this thesis, I chose two vignettes to explain the use of the spiral of working theory development model as an analytical framework. These vignettes are presented after table 3. As I have noted, the purpose of the examples in table 3 is to provide an indication of the breadth of data generated and analysed in this research. The table includes an example for each of the STEM domains, then an example of integrated STEM.

Table 3.

Stem related working theories

Science related working theories	
Description of the experience	Examples
Developing working theories about jelly crystals dissolving. A group of children and a teacher were making jelly together.	A teacher asked, “where did the [jelly] crystals go?” while they were being stirred into the hot water. Rebecca (child), “in the back”. The group of children and teachers then talked about jelly crystals, using magnifying

	glasses to look at dry crystals and looking into the wet mixture to find the crystals. When Rebecca was asked later about where the crystals had gone, she replied, “it’s gone boiled” (Rebecca/VD).
Technology related working theories	
Description of the experience	Examples
Developing working theories about a safe design. A group of children and a teacher were problem solving how to safely transport two bicycles in a van.	After thinking of a few ways to transport the bikes, a child said, “or you can just put it behind the, the peoples seat and then it will just stay there”. He next decided that he could hold the bicycle beside him while sitting in the van. However, a teacher challenged his working theory by wondering aloud if the bikes would move if the van stopped suddenly saying, “but sometime when the van sudden[ly] stop and the force just come[s] like this” [she clapped her hands to demonstrate]. Another child stated, “the bikes will just push off, the bikes wheels will just push and then [he crashed his hand into the mat] fall and break”. The children then discussed the pros and cons of holding the bikes sideways so they would not roll if the van stopped suddenly. They then discussed and developed further working theories about safely transporting the bicycles including laying the bicycles under the seats, placing wooden blocks under

	the wheels, using a bicycle rack, and eventually settled on placing the bicycles in a trailer towed behind the van. (Sarah/VD).
Engineering related working theories	
Description of the experience	Examples
Engineering a solution. The children were collecting lemons from a tree to make lemonade but could not reach the lemons on the higher branches.	Frank watched a teacher and another child pull on a branch to lower it to allow the lemons to be reached. The branch did not move much. Soon after, Frank climbed up a different branch and shook it to knock the lemons off. Through trial and error, he found that if he pulled on a branch while it was moving towards him it moved even further. Eventually a lemon fell off. Frank went back to the original branch that did not move much and used his new technique. He had worked out how to pull the branch further down, working with the natural movement of the branch, waiting for it to spring back up and then pulling it once it was moving down again. (Frank/VD).
Mathematics related working theories	
Description of the experience	Examples
Developing working theories about basic algebra. A group of children and a teacher were working out quantities required for baking. The teacher wanted to double the recipe and	Teacher: “Do you know how we normally bake? Just bake three bananas with one teaspoon…of…baking powder?” and she held up three bananas. “But this time we’re gonna make [use] six [bananas]. So how many [teaspoons of baking powder] do you think?”.

was trying to help the children work out the doubled quantities.	The children responded with various, seemingly random amounts. Eventually the teacher laid down three bananas and placed one teaspoon on top of the three. She then took the remaining three bananas and placed a second teaspoon on top of them. The children responded that two teaspoons were needed. (Sarah/VD).
Integrated STEM related working theories	
Developing working theories about all four STEM domains. A teacher and some children were preparing for a soccer match by working out how to attach player numbers to their shirts.	Mathematics This was an extended episode where the children and teacher first worked out how many players should be on each team, then compared the number of players on each team, and worked out numbers of players required to have equal teams. Children were developing working theories about comparison, addition, and subtraction as they discussed the numbers, counted and calculated. Technology The children and the teacher then designed a way for the two teams to be distinguished. Ideas ranged from painting shirts different colours to bringing a shirt that was already the correct colour for the team the player was on. Engineering The children decided that each player needed

	a number on their shirt, and had to engineer a solution to allow numbers to be attached to shirts. Solutions ranged from sewing material with numbers on to the shirts, to safety pinning on material with numbers on, to painting the numbers on the shirt, to writing numbers on paper and then using glue or sticky-tape to attach it to the shirt. The children agreed to trial paper and sticky-tape, but on testing found it did not stick for long. They re-engineered a solution by using large stickers in place of the paper. Science While working out how to stick the paper to their shirts, the children shared and developed their working theories about the properties of sticky-tape and glue. They talked about the different types of glue they could use, and the length of sticky-tape required to adhere the paper to their clothing. (Thomas/VD).

The above table provides a small representation of the breadth of data, indicating some of the working theories that were being developed about the STEM domains. The two following vignettes explain the use of the spiral of working theory development model as an analytical framework. I have chosen both of these vignettes as they were extended episodes of teaching and learning which I observed where working theories about the STEM domains were being developed. I also engaged in further discussion about each of these vignettes with the teachers involved which provided insight and understanding into the experiences. I explain both vignettes next, then use the spiral of working theory development model as a framework of analysis.

Castle construction

The following excerpt is part of an extended episode where a group of 4-year-old children at Charleston were building a castle using small wooden blocks. A teacher suggested that they use a ruler to measure the height of the castle, which the children did, and then proceeded to build the castle higher. With the encouragement of the teacher, a child—Jack—tried to measure the height of the castle with a ruler. However, the castle exceeded the length of the ruler, so following the suggestion of the teacher, and with her help, Jack used sticky-tape to join two rulers together end on end to measure it. He then decided to tape the rulers to the base of the castle to free his hands up for more construction. Jack applied two small pieces of tape across the bottom of the ruler and across the base. However, after a while, he found that the rulers fell over (the tape was not long enough to adhere well). Another child—Rebecca—suggested: "you need a long long long as sellotape™ so it can hold it", pulling a long piece of tape off the dispenser, "like that long". She passed it to Jack whose slow response, and facial expression indicated he first thought carefully about the placement. He then applied it vertically, along the lengths of the rulers only. However, while doing so the rulers became inadvertently balanced and stood up. Rebecca noticed, to her surprise: "Wait, we just need to, Hey! It's sticking straight". She was at first surprised, but then copied Jack by carefully applying tape to the rulers, either choosing to place it vertically along the rulers or around them and announcing, "Standing straight now" (Rebecca/VD).

The following table indicates possible working theory enrichment through this experience.

Table 4

Possible working theories from castle construction

Working theory	**Who**	**Working theory built through**
Sticky-tape must be applied across the joint to connect the rulers together	Jack	Past experience
Sticky-tape must be placed across the joint between the rulers and the block to connect them (length is not an issue)	Jack	Past experience

Working theory	Who	Working theory built through
Sticky-tape applied across a joint does not provide stability	Jack	Trial and error
A longer piece of tape is required (length is an issue)	Rebecca	Relating past experiences to current situation
Location of the tape does not matter—only the length does (placing it along the rulers which stand up as they are inadvertently balanced)	Jack	Trial and error
Perhaps location does matter (Rebecca placed a small piece of tape across the joint, but seemed confused)	Rebecca	Current experience disrupting past experiences
Location does not matter	Rebecca	The evidence from the experience outweighs her already held working theory

The children appeared to hold a working theory that the rulers could be supported by the addition of reinforcing materials, and in this case, sticky-tape. However, their working theories about application and placement of the tape were conceptually inaccurate. The evidence inadvertently supported the inaccuracy that tape does not need to be placed across joints, but only around one piece of construction material.

On re-viewing the video footage, I found the individual STEM domains and concepts to be prominent in this episode. For example: science—gravity, force, energy; technology–the design process, evaluation, problem solving; engineering—constructing, testing solutions, considering alternatives; and mathematics—geometry, patterns, height, and comparison. However, it appeared that in the moment of teaching and learning, the children and teacher were likely not aware of the individual domains. Instead they worked collaboratively together, building, measuring, and problem solving. I contend that the teacher and children engaged in an experience that was more holistic than a science, technology, engineering, or mathematics activity. In this regard, I argue that the four STEM domains were integrated in this experience.

Climbing frame

The second excerpt is again part of an extended episode, this time involving a group of 3 and 4-year-old children who had been trying to reach the overhead bars of a climbing frame. They first started by standing on the ground directly underneath the bar and reaching up, standing on their toes and stretching as far as they could reach. A child suggested they jump, which they tried next, and while some could touch the bar no one could hold onto it and swing. Another child suggested they all go to the top of a nearby rise, run down it, and jump. Again, they all tried this but found that they still could not hold onto the bar. One of the children saw a large foam wedge which he dragged towards the climbing frame. The children ran down the rise and up the wedge to reach the bar. Many children tried this, finding that the wedge was a little unstable and could tip, effectively acting as a seesaw. If they jumped from too high up the wedge—above its pivot point—it was likely to tip over. The following excerpt details Poppy's—a 4-year-old girl's—enrichment of her working theories as she observed other children, and then attempted to reach the bar herself.

After watching Frank (another child) use the wedge both successfully and unsuccessfully, Poppy set off down the hill determinedly, but when she jumped onto the foam wedge it was a little unsteady. Her first point of landing was right on the pivot point and the wedge wobbled slightly, so she jumped backwards a little and continued to do small jumps at the bottom of the wedge.

Frank called out, "you just jump, jump on the bars!".

Poppy continued jumping then tentatively stepped upwards along the wedge and reached the bars easily and swung for a while.

After watching some other children, it was Poppy's turn again. She ran down the rise slowly, and tentatively jumped onto the bottom of the wedge as if she was testing it out. Frank called, "3, 2, 1, jump!" Poppy carefully tiptoed up a little higher then launched herself onto the bars. Because she was so tall, she could jump from well below the pivot point.

A little later, Frank told Poppy that it was her turn. Poppy replied, "I want it closer" [meaning the wedge closer to the climbing frame].

Frank said, “You wanna run” and he ran slowly down the rise, put one foot on the wedge and turned to Poppy “cos you’re scared of the heights”. Poppy nodded, and Frank moved the wedge closer to the bars.

Poppy jogged down the hill and bounced nearly on the bottom of the wedge. She bounced up the wedge a little higher putting her hands down to steady herself, then took a couple of steps up and jumped to the bars. She seemed very apprehensive. As she was swinging her feet made the wedge topple, but she corrected it while still swinging.

A little later, Poppy ran down the hill slightly faster than previously and jumped further up onto the wedge. She bounced twice, launched and grabbed the bar. She seemed much surer of herself now.

Later again, Poppy had a final turn, now seeming more assured, though still careful. She took one jump up onto the wedge, steadied herself then jumped to the bar, swinging vigorously before dropping to the ground.

The following table indicates possible working theory enrichment through this experience.

Table 5

Possible working theories from climbing frame jumping

Working theory	**Who**	**Working theory built through**
If we stretch, we can reach the bars	Many	Past experience, observation of others
If we jump, we can reach higher	Many	Past experiences, observation of others
If we run fast and jump, we can reach higher	Many	Past experience, building on each other’s thinking
We can use equipment to help us reach higher	Many	Past experience, building on each other’s thinking
We can run down the rise, up the wedge and jump to reach higher	Many	Building on each other’s thinking

Working theory	**Who**	**Working theory built through**
The wedge is unstable	Many	Jumping on the wedge, observation of others
The wedge has a pivot point	Poppy	Jumping on the wedge, observation of others
If I jump from below the pivot point, the wedge will not tip	Poppy	Trialling small jumps
If I step up the wedge carefully, I might not overbalance it	Poppy	Careful climbing
I can jump from below the pivot point, not overbalance the wedge, and reach the bars	Poppy	Trial and error
If the wedge is too far from the bars, I will not be able to reach it	Poppy	Observation of Frank, gauging distance and gauging ability
I can bounce safely near the bottom of the wedge	Poppy	Experimenting
I can land a little higher up on the wedge without reaching the pivot point	Poppy	Experimenting, observing others
I can be more sure of myself	Poppy	Repeated practice, feedback gained from the practice

Together the children enriched their working theories about many domains. For this vignette, I have focused on STEM related working theories identifying, as with the previous vignette, STEM concepts and domains as being prominent in this episode when re-viewing the video footage. For example: science —velocity, energy, biomechanics, force; technology—designing a solution to a problem the children have set for themselves; engineering—trial and error, using suitable materials, logical structure to solving a problem; mathematics—vectors, comparisons, geometry, distance. Again, the children were not focused on a particular domain. Instead they were focused on a common goal which incorporated all four STEM domains. The children's working theories seem to be underpinned by working theories that we can work together to problem solve, and there are ways of reaching higher.

Poppy's actions and progressively more assured approaches indicate that her working theories about how to use the wedge to reach the bar were enriched. These working theories likely included the speed she needed to run at, her angle of approach, the height of her jump, her placement on the wedge, her body position and the mechanics of using her body.

Discussion

The two models introduced earlier provide insight into the children's working theories in both vignettes. First, the three-fold view of working theories: conceptualising working theories as a combination of process, outcome, and interpretive framework. Second, the spiral of working theory development: highlighting children's working theories enrichment occurring through a recursive process of understanding, experience, information, and making connections.

Castle construction

The castle construction vignette illustrates the earlier conceptualisation of working theories as being three-fold: the process of enriching the working theory, the working theory itself as an outcome, and the working theory as being an interpretive framework of further working theories. Rebecca's and Jack's enriching working theories appeared to be underpinned by a deeper working theory—that sticky-tape aids construction—which guided their actions. They both worked through the process of using tape to help provide stability to the rulers. Inadvertently, due to the rulers becoming balanced without tape being applied across the joint, their working theory became that location of the tape does not matter. The underpinning working theory still remained: sticky-tape still aided construction. However, their working theory now also encompassed the understanding that location did not matter. The three-fold nature of their working theories can be visualised in Figure 9.

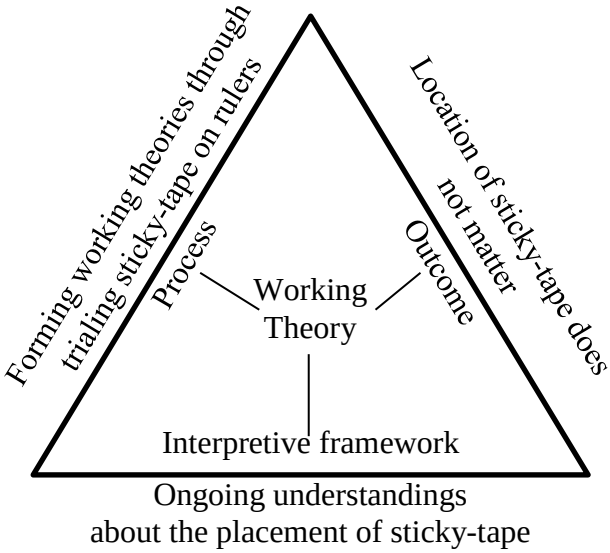


Figure 9. A three-fold view of working theories in castle construction.

In this conceptualisation, the process, outcome, and interpretive framework are inextricably linked. The underpinning working theories—that sticky-tape aids construction—influenced all aspects. After all, if this working theory had been entirely different, then sticky-tape might not have been used. The process of forming the working theories then influenced the outcome aspect, which then refined the interpretive aspect, through which subsequent processes and outcomes were filtered. In short, all aspects were linked and impinged on each other.

The spiral of working theory development model provides insights into the enrichment and elaboration of the children's working theories. For example, the model can be applied to Rebecca's developing working theories about the use of sticky-tape to provide stability for construction (see Figure 10). Each iteration shows two instances of understanding: First (and denoted as 1) is the initial understanding; second (and denoted as 2) is the resultant understanding after moving around the spiral. The resultant understanding of iteration 1 then becomes the initial understanding of iteration 2.

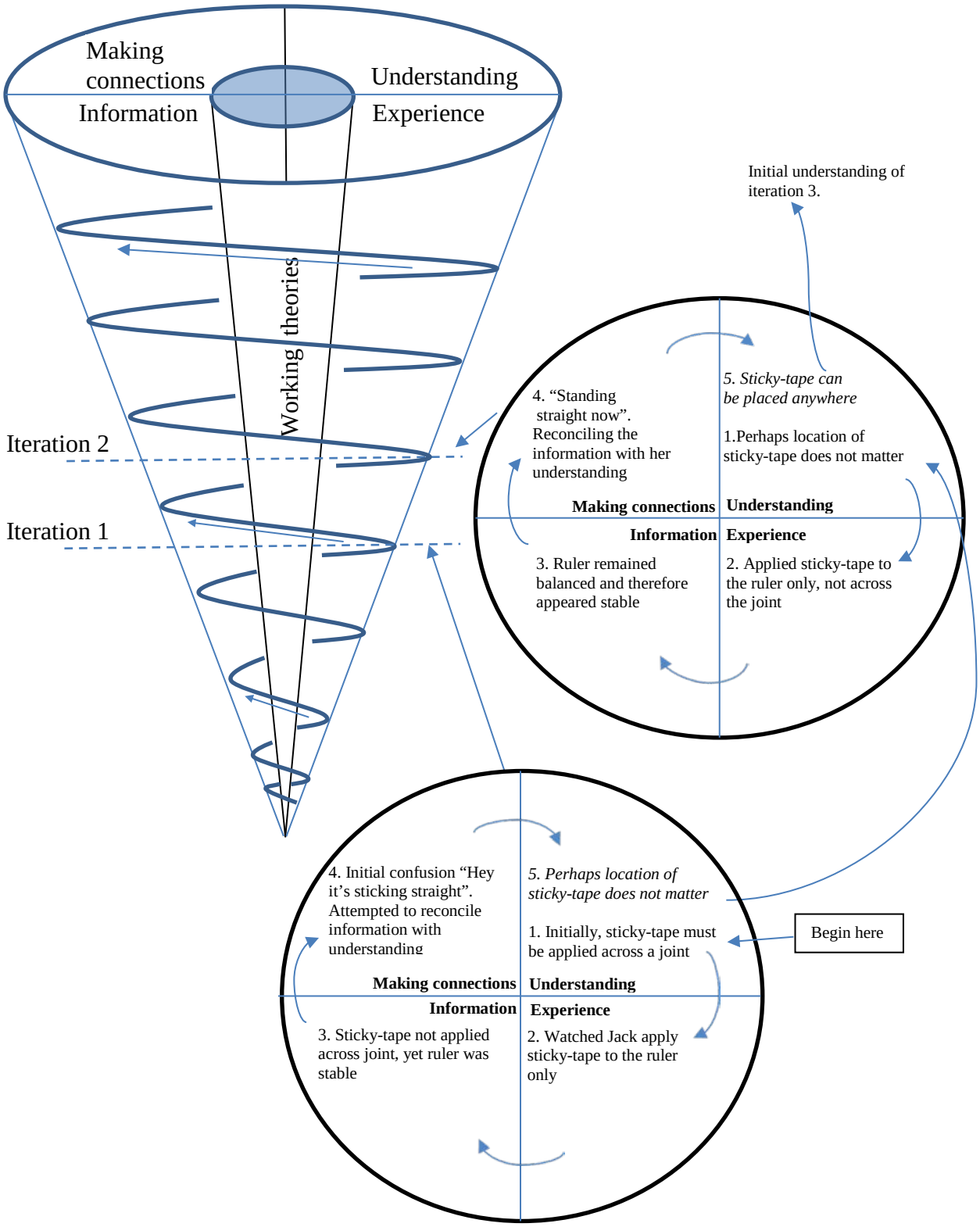


Figure 10. Rebecca's enriching working theory showing two iterations.

As highlighted earlier, working theories encompass all four elements of the spiral. Therefore, Rebecca's working theories encompassed evolving understandings, experiences, information and making connections. Importantly, although shown only once, iteration 2 likely occurred

over repeated cycles. This is because Rebecca experimented with her placement of the sticky-tape numerous times before her eventual announcement that it was standing straight. From a conceptual accuracy perspective, Rebecca's working theory was not developed in a logical, structured way. However, an interpretivist, social constructivist perspective highlights that there is logic and structure to Rebecca's working theory. Rebecca drew on the information from her experiences and made sense of it to form her working theory. Through further experiences in her life, it is likely that she will revise her working theory about the placement of sticky-tape again.

Climbing frame

As with the castle construction, jumping to reach the bar also involved a three-fold view of working theories as depicted in Figure 11. First, the interpretive framework component of Poppy's working theories was that using the wedge would help her to reach the bar. Second, through trial and error, Poppy worked through the process of enriching her working theory about the use of the wedge. Finally, the outcome was that she developed some initial working theories about the placement of her body on the wedge. Poppy's attempts to reach the bar appeared underpinned by the working theory that using raised equipment would help her reach higher.

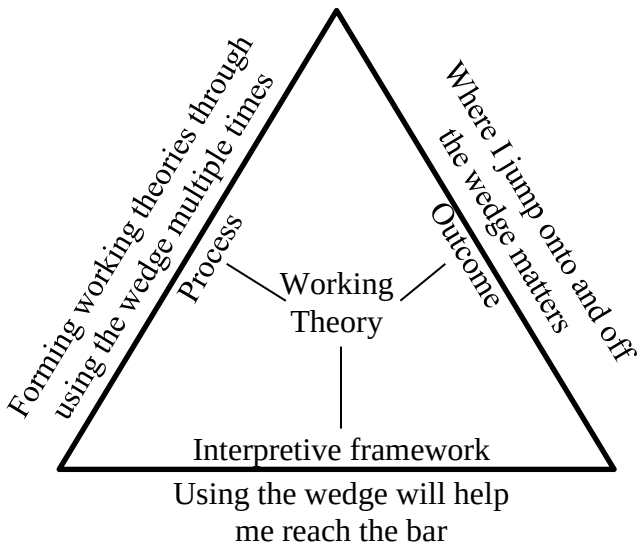


Figure 11. A three-fold view of working theories about jumping onto the climbing frame.

Poppy's underpinning working theory—that raised objects would help her reach higher—influenced the three-fold aspects of working theories and meant that she was motivated to

experiment. As she experimented, Poppy worked through the process of forming working theories, enriching outcomes which then functioned as a revised framework to filter subsequent attempts. Again, the spiral of working theories provides insight into the development of her working theories about jumping from the wedge to the bar.

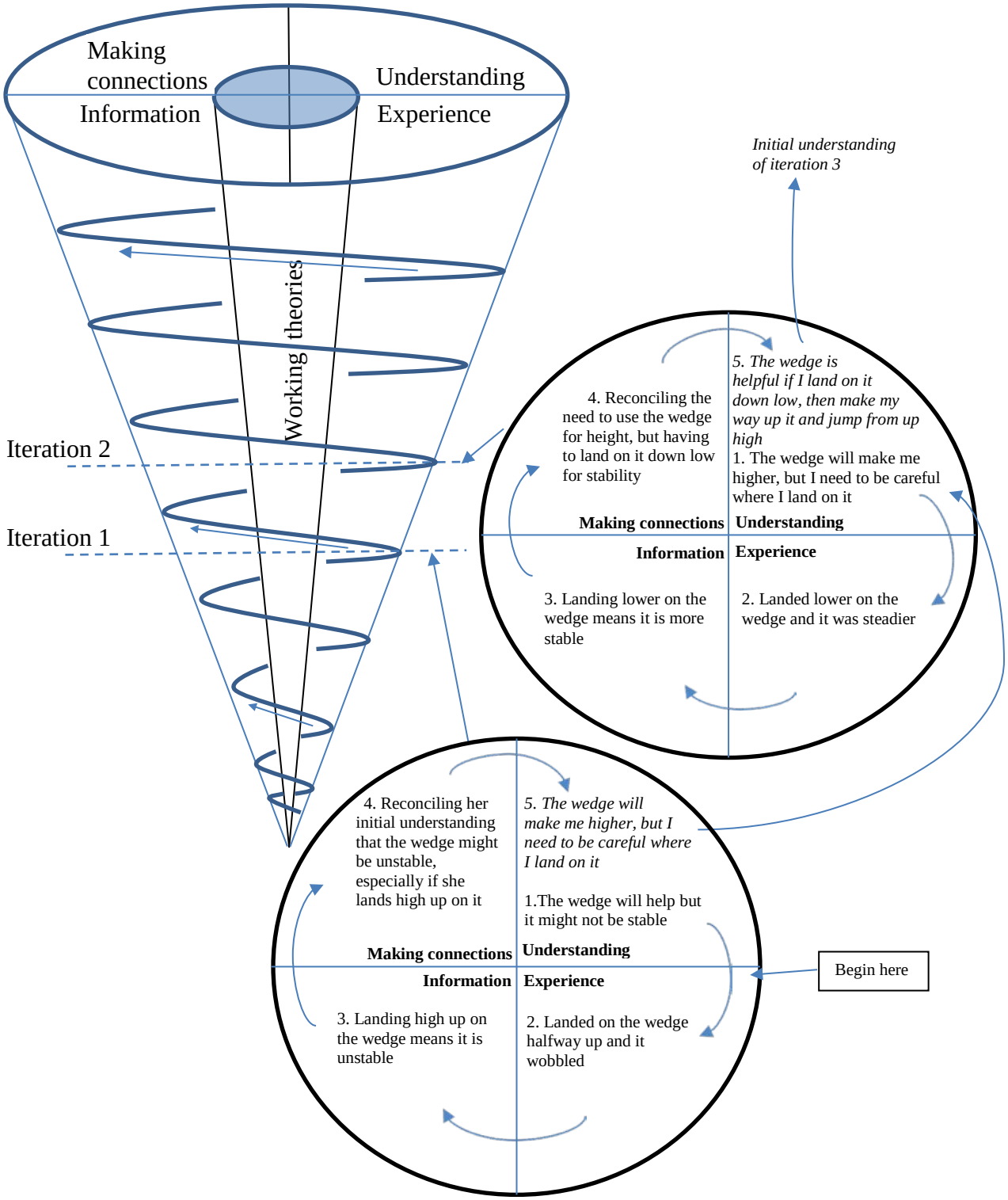


Figure 12. Poppy's enriching working theory showing two iterations.

Again, the two iterations are a small part of multiple iterations that Poppy worked through. Further iterations would have occurred through her experience of jumping onto and off the wedge multiple times. Furthermore, it is like that each time she jumped up and down on the wedge she was going through another iteration as the experience of jumping up and down in the same place provided further information. And lastly, Poppy likely went through more iterations as she observed and listened to other children as they also attempted to use the wedge to jump onto the bars.

Conclusion

Working theories are one way that knowledge, skills, and attitudes are described as combining in *Te Whāriki.* The notion of working theories is complex, involving knowledge, skills and attitudes, enabling children to build enriched understandings to make sense of the world, and to develop a sense of self as explorer and learner. I have presented a visual representation of working theories as being three-fold, involving the aspects of process, outcome, and interpretive framework. Furthermore, I have presented the development of working theories as a recursive spiral including four elements: understanding, experience, information, making connections and new understanding. The three-fold view, and the spiral of working theory development model are unique views of working theories which might inform curriculum planning, teaching approaches and demands for a focus on academic skills in ECE, as working theories are recognised as much more than simply naïve thinking.

Enriching, broadening and developing working theories is a complex, socially and individually influenced process as all four elements of the spiral of working theory development model link to many areas of children's lives, understandings and working theories. We cannot predict where working theories will head. Multiple possibilities will arise from the understandings, information, experiences, and connection making for any child involved in the same experiences and activities. I offer the spiral of working theory development model as a way that permits new insights into the complex ways that working theories are enriched, elaborated and broadened. The model brings certainty and uncertainty together, that is the certainty that the four elements offer one way to describe the process of working theory development. This certainty is offset with the uncertainty of where the working theories might head. The model offers significant insights to understanding learning, influencing teaching approaches, and offers further possibilities for research.

Understanding how working theories are developed is a necessary foundation on which teachers can base approaches that foster working theory development. Teaching approaches that foster and enrich working theory development are the theme of the next chapter.

5. Teaching approaches

Introduction

Early childhood teachers have a key responsibility to foster and enrich young children's working theories (MOE, 2017). As I argued in chapter 4, children's working theory development affords knowledge, skills, and attitudes for young children, potentially leading to ongoing and developing understandings of the world, and problem solving skills that develop and can be used throughout the child's lifetime. As I argued in chapter 3, a focus on the STEM domains can enable children to develop knowledge, skills, and attitudes that lead to a better understanding of the world. These understandings can lead to ongoing STEM related interests, and informed decision-making about complex issues and challenges that the world faces. Therefore, it is important that children develop and refine working theories about the STEM domains, meaning that an understanding of teaching approaches that foster those working theories is needed. Fostering children's working theory development is a highly complex and demanding role for teachers (Hedges, 2014; Peters & Davis, 2015; Peters et al., 2018). Research into teaching approaches related to the development and enrichment of working theories about the STEM domains is therefore critical.

This chapter addresses research question 3: How might teachers foster and enrich young children's working theories about the STEM domains? Similar to chapters 3 and 4, I begin with a review of the literature pertaining to the research question. I then present the shared learning commitments (SLC) model which was developed throughout the research process. Next, I present findings from the data, analysed through each element of the SLC model, before presenting one vignette to illustrate the complete model. Next, I discuss the SLC model in relation to the vignette, and end the chapter with concluding comments.

This chapter is based on an assumption that teaching approaches aim to enable children to "engage confidently, calmly and capably with situations that are complex and fast-changing." (Claxton, 2015, p. 374). This means that young children's accurate conceptual knowledge is important, but regarded equally with skills and attitudes, which are the other aspects of working theories. Therefore, teaching approaches are about working with children to build their knowledge, to grow their skills and to develop positive attitudes towards learning, problem solving and thinking.

The SLC model which I have developed through this research builds on the spiral of working theory development model to highlight how teachers might foster working theory development. As I described in chapter 2, the model development was a recursive process, initially developed from synthesising and critiquing prior literature, and subsequently revised through data analysis and theorising. The model is a representation of the teaching approaches related to working theory development in the context of this research. It could be used as an analytical tool by both academics and teachers to provide insight into teaching approaches. Furthermore, the SLC could provide a guide for teachers to understand their current teaching approaches, and develop further approaches that foster working theory development. The model could also provide a starting point for further research to investigate teaching approaches in different contexts.

The SLC model includes four elements: a central element of understanding, surrounded by three further elements: providing intentional experiences, making selected information visible and making connections. By underpinning teaching strategies with the SLC model, teachers can focus on forming deep understandings of children and their working theories, leading to potentially meaningful teaching responses that result in enrich, elaborated and broadened working theories. Before I move any further, it is important to define and explain some critical terms related to teaching for this research.

Three terms are critical to this chapter and therefore need explaining. First, is the term teaching approaches which I have explained in chapter 1. To recap, this term is consistent with my conceptual framework, the informal nature of learning in ECE contexts, and the non-prescriptive nature of *Te Whāriki*. Teaching approaches refers to the broader style or general way that the teacher goes about teaching, based on the teacher's broad theoretical frameworks, and pedagogy. The notion aligns with a sociocultural view of teaching and learning where learning is built through engaging in culturally meaningful experiences with others (Fleer, 2010). Teaching approaches are not the technical strategies that a teacher might use. They represent, in much the same way that *Te Whāriki* does, space for teachers to negotiate and weave their place within children's working theory development.

The second and third terms that require explanation are foster and enrich. The term foster relates to the influence that a teacher can have on a child's developing working theory. In keeping with the mediational theoretical layer which I add in chapter 6, a teacher cannot make a child's working theory change, and they cannot make a child hold a specific working theory.

Instead, a teacher can guide and support children's learning by engaging directly with the children (Siraj-Blatchford, 2009) and by encouraging engagement in meaningful experiences (Fleer, 2010). By using the term foster, I am referring to the teacher encouraging development, and acting as a guide with a dynamic and flexible aim that a child's working theory is enriched and broadened in some way. The term enrich means that the working theory is extended or becomes broader by encompassing new information. This does not mean that the working theory becomes more conceptually correct. The conceptualisation of working theories as being three-fold which I explained in chapter 4, means that enrichment of working theories can be viewed as three-fold. This perspective means that the aspects of process, outcome, and interpretive framework are enriched, enabling a child to better make sense of the world. I have used these deliberately to counter calls for teaching that might only seek to aim children's working theories towards points of conceptual accuracy.

Literature Review

This section presents a critical review of literature related to everyday teaching approaches. To begin with, I review literature related to teaching STEM in ECE. I then review literature related to teaching associated with working theory development. Finally, I review literature which I built on to develop the SLC model, and which is presented later in this chapter.

Teaching STEM in ECE

The provision of materials and equipment as a response to children's interests, and as a teaching approach leading to STEM learning is consistently highlighted in literature. Teaching approaches related to STEM education in ECE are predominantly constructivist or sociocultural as I outline next.

Constructivist teaching approaches related to STEM education abound. These are often teacher designed and planned, in response to children's interests. I provide a small example of such opportunities from the literature next. From a science perspective, natural materials, such as stones, plants and seeds can be provided for children to use creatively in their everyday play (Campbell & Cutter-Mackenzie, 2015). From a technology and engineering perspective, drawing equipment, and real tools such as hammers and saws can be provided for children to problem solve, design, construct and evaluate (Cooper, Johnstone, Rotchell, & Woolley, 2010). From a mathematics perspective, teachers can introduce manipulatives for children to enrich their understandings of numbers, comparison, and patterns (Jung & Conderman, 2013).

Provision of these or similar experiences may lead to STEM related learning, however, on their own, these approaches can be considered constructivist, relying on the children's interaction and exploration of the objects and materials.

The constructivist approaches identified in the literature might be a result of reduced teacher engagement in STEM teaching and learning. Moomaw (2013) noted that reduced engagement leads to little dialogue between teachers and children, instead relying on children to learn through exploration themselves. Furthermore, McClure et al. (2017) noted that STEM learning occurs even if teachers are not engaged in teaching STEM, perhaps lessening the demand felt by teachers to engage in STEM related teaching. Bagiati and Evangelou (2015) contended that there is a fine line between teacher guidance and children's free exploration of materials and equipment, suggesting that both can be accomplished through close observation and careful intervention by the teacher. Similarly, Moomaw (2013) argued that a combination of real-world exploration, together with teaching of concepts and teaching of the vocabulary related to the concepts is needed for children to understand STEM concepts.

From a sociocultural perspective, and aligning with *Te Whāriki*, ECE settings are ideal contexts for STEM teaching to be integrated into children's everyday learning experiences (Saracho & Spodek, 2008a). By building on everyday moments, teachers can work purposefully with children to provide meaningful experiences which foster STEM learning (Lindeman et al., 2013). Teaching STEM in ECE can focus on teaching and learning experiences which are engaging, absorbing, challenging and sustained for the children (Katz, 2010). These experiences can also focus on children's interests, their prior experiences, and prior knowledge (Tippett & Milford, 2017). The idea of providing meaningful STEM experiences is significant for this research, and raises the issue of how meaningful teaching and learning experiences might be provided and what teacher decision making could be based on. To be meaningful to children, STEM related teaching and learning experiences need to be founded on close observations, an understanding of the children and their interests, and an understanding of how children learn (Bybee, 2013; English & Moore, 2018). This thinking is significant to my research. I build further on it later in this chapter when I introduce the SLC model.

Four STEM teaching practices were identified by Moomaw (2013): intentional teaching; teaching for understanding, encouraging inquiry, and providing real-world contexts. The perspective of providing meaningful teaching and learning experiences can be used to interpret these four practices. First, according to Moomaw, intentional teaching about STEM means that

the teacher has conceptual understandings about STEM, and can therefore bring a focus and hence an intentionality on STEM to teaching and learning experiences. Second, teaching for understanding can be interpreted as meaning the teacher needs to understand the children's existing understandings and the influences and experiences that led to those understandings. Then the teacher can build on and develop those understandings. Third, encouraging inquiry can be seen as understanding the interests of the child and then understanding the teaching approaches that prompt inquiry about those interests. Fourth, providing real-world contexts can be thought of as understanding what is real-world for the children, then drawing on that understanding to provide engaging and absorbing real-world contexts.

This perspective is consistent with my conceptual framework which is explained in chapter 1, and with prior research about working theories explained in chapter 4. To recap, the research about working theories by Hedges and Cooper (2014a), identified the importance of understanding children's interests and inquiries using a funds of knowledge approach. This perspective emphasised that deep interests were a key motivator to developing working theories, and that life experiences influence children's working theories. From a conceptual framework perspective, I brought together sociocultural and social constructivist theoretical perspectives within an interpretivist paradigm. Bringing these perspectives of my conceptual framework to the literature means that teaching approaches related to STEM education in ECE require first, an understanding of the children, of their experiences, and of their knowledge. Second, teaching approaches should be founded on an understanding of how children learn. Third, based on the teacher's understanding of the children, teachers should respond by providing meaningful teaching and learning experiences related to STEM.

Teachers' subject knowledge

As I argued in chapter 1, teacher subject knowledge can be considered as a significant affordance or constraint of everyday teaching of STEM within ECE (Bagiati & Evangelou, 2015; MacDonald & Rafferty, 2015). Little STEM subject knowledge could impact teacher confidence, leading to insecurity, negative perceptions, and to potential STEM related learning opportunities being avoided or not recognised (Kumtepe & Genc-Kumtepe, 2015). Therefore, opportunities for children to enrich working theories about the STEM domains might be lost, resulting in a low provision, low response curriculum (Hallström, Elvstrand, & Hellberg, 2015). As I explain later in this chapter, to engage in a shared learning commitment with children, teachers need to understand the interest or inquiry of the child/children. Therefore,

some subject knowledge is required. However, as Wood and Hedges (2016) argue, the issue of teacher knowledge is contentious and in need of further debate and discussion—teachers (or anyone) cannot be experts on everything. The view that teachers must hold deep subject knowledge to teach concepts has been a subject of Fleer's ongoing research. Fleer and Raban (2006) noted that a depth of subject knowledge is critical when teaching concepts. However, in later research, Fleer (2009) found that teachers' beliefs about how children learn are more important than teacher subject knowledge, confidence and competence.

By focusing on fostering and enriching working theories, I argue that the contentious place of teacher subject knowledge is lessened. In chapter 4, I argued that working theories involve knowledge, skills and attitudes, and can be viewed as three-fold: process, outcome and interpretive framework of further learning. Taking this perspective of working theories means that teachers can be viewed as facilitators of working theory development, focusing on knowledge, skills, attitudes, process, content, and the development of working theories as interpretive frameworks. Subject knowledge therefore remains important, but not the only focus. Instead, the focus shifts to teachers' attitudes towards learning about new STEM related concepts with children. Teachers' attitudes influence their involvement in potentially unfamiliar STEM related teaching and learning opportunities. By becoming involved in these opportunities, teachers can build their subject knowledge together with children, also focusing on the process and skills involved. This view, in conjunction with a positive perspective to unfamiliar subject content, is consistent with the findings of my research as I detail in the findings section.

Supporting working theory development

Within the New Zealand ECE context, past research has highlighted the importance of supporting, developing, extending and building young children's working theories. As I have explained, my research investigated teaching approaches which I have described as being a step back from specific teaching strategies and which might be considered as being the deeper and underlying approaches that then lead to specific strategies. Therefore, this section focuses on teaching approaches as I perceive them to be in the literature.

In chapter 4, I identified four large-scale research projects involving working theories, then moved to postgraduate studies and a small scale project. Consistent with that approach, I also outline the findings of these projects next in regards to teaching approaches next.

From the first large scale project involving working theories, six teaching strategies to support children's learning in general, rather than their working development were identified (Simmons, Schimanski, McGarva, Cullen, & Haworth, 2005). While the strategies were presented as ways to support complex and sustained learning, they have significance to my study, being developed through research about working theories. The strategies were: being aware that children need to revisit learning, and providing opportunities to do so; moving between co-construction and scaffolding; integrating resources together; having fun; asking open-ended questions; and promoting peer interactions to support learning.

In the project led by Davis and Peters (2011), the following teaching approaches were identified: being attuned to children's working theories; supporting the development of ideas, curiosity and wonder; and creating spaces for uncertainty. These approaches were based around the theoretical constructs of intersubjectivity and mutual understanding between teachers and children, sustained shared thinking (SST), and mediation—in particular the zone of proximal development, co-construction and scaffolding. The authors noted that knowing the child well was important as it attuned teachers to the children's working theories, the development of mutual understandings and SST. In further publishing from the project, Peters and Davis (2011) discussed the dilemmas teachers face about which working theories they decide to respond to, when to focus on providing conceptual facts, and when to disrupt children's working theories. In later publishing, Davis and Peters (2012) focused on the issue of teachers hijacking or diverting the exploration involved with working theory development, and offered "ways of being" (p. 177) for the teacher when involved with working theory development. These ways of being included provoking and inspiring children; being prepared to make a judgment about where the child is heading; questioning the teaching and learning process; foregrounding the learning journey over the right answer; being intentional; creating an environment where it is acceptable to think and be different; shifting the power balance between teacher and child; and acknowledging that relationships are the key, built on knowing the child and their home-life.

I introduced Hedges and Cooper's (2014a) research in chapter 4, explaining their study in relation to the development of working theories. Their second research question asked: How might teachers notice, recognise, respond to, record, and revisit infants', toddlers', and young children's interests, inquiries, and working theories in early childhood education? In addressing this question, they identified that recognising children's deep interests, inquiries and funds of knowledge (González et al., 2005) led to teachers being able to use approaches that enabled development of working theories. They noted that approaches such as slowing down, and

avoiding assumptions were required, based on looking deeper into children's real interests, not just their activities. Hedges and Cooper noted the significance of home visits as enabling teachers to understand children's inquiries, interests and funds of knowledge. The understandings gained led to teachers being able to recognise and understand children's interests and motivations and respond accordingly. They noted three categories of response: providing opportunities to choose activities enabling representation of family interests; involvement in interactions with children that gently challenged children's theorising and knowledge building; and puzzling over interests and inquiries together. In later publishing, Hedges (2015) noted the challenge of knowing when to challenge working theories and when to provide conceptual knowledge. She suggested that at times it might be best to promote the process of working theory development, and the associated curiosity and thinking skills over conceptual accuracy. She noted the importance of knowing children well, as enabling teachers to make professional judgements and provide meaningful and relevant experiences.

As I described in chapter 4, Peters et al. (2018) built on the earlier work of Davis and Peters (2011). They identified the following teaching approaches: providing authentic learning opportunities; building on existing interests; engaging with children as they explore; focusing on working theories; and providing opportunities for children to share ideas and understandings. They also identified the theoretical construct of mediation and in particular, co-construction as being important to fostering working theory development. In further writing about the project, Davis and McKenzie (2017) noted the importance of listening to children to identify their working theories and to recognise what they were really about. In a later chapter (Peters et al., 2018), they identified that teaching approaches should be sensitive and attuned to the children, focusing on intersubjectivity and mutual understandings.

Postgraduate research has also been undertaken to investigate teachers' roles in working theory development. Hargraves (2011) identified approaches such as fostering dialogue, facilitating interactions and experiences; guiding and focusing attention, and stretching thinking. In my prior research (Lovatt, 2013), I identified approaches consistent with Hargraves, noting the importance of carefully introducing new experiences based on knowing the child; engaging in sustained dialogue; and carefully and actively challenging children's thinking. Both studies noted the importance of mediation in fostering the development of children's working theories. Kelly-Ware (2018) noted that teachers can open up or close down children's working theories, and that complex issues only recognisable through close observation and listening might be represented in working theories. In a later article she identified that slowing down was

important and attainable through observing, waiting and engaging with children (Kelly-Ware, 2016). In a further article, Areljung and Kelly-Ware (2017) raised the importance of teachers giving voice and their time to children's working theories. Hill (2015) also identified the importance of close and careful observations accompanied with sensitive responses.

Similar findings have been presented from the two small-scale research projects. Kelly et al. (2013) identified that based on a mediational lens, and in particular scaffolding and co-construction, careful listening and observation is needed to enable understanding of working theories. Consistent with these findings, Sands et al. (2012) found that deep listening, slowing down coupled with providing time and space enabled deep involvement by teachers in working theory development.

Using the perspective of my research which focuses on teaching approaches rather than specific strategies, a number of common themes can be identified across the literature. These themes include: First, teachers need to know their children well. They can do this through approaches such as careful and close listening, observing and undertaking home visits. Second, teachers need to be attuned to children's working theories. Again, this is through listening and observing, but also through foregrounding the notion of working theories. Third, teachers should engage with children, entering into mindful dialogue, providing resources and encouraging peer interactions. A common theoretical construct underpinning these approaches is the notion of mediation which is the theme of chapter 6.

Dilemmas around children's working theories were highlighted by Peters and Davis (2011) who identified two issues: First, how to recognise a child's working theory, and second, how to respond. Hedges and Jones (2012) noted that teachers need to hold deep understandings about working theories to respond appropriately and meaningfully to children. At the same time, they also noted that teachers struggled to explain the concept of working theories, appearing to hold intuitive but difficult to articulate understandings. Once teachers develop their own understandings about working theories, they might then put on their metaphorical "working theory glasses" (Davis & Peters, 2011, p. 5) to become attuned to the children's working theories, and then to respond meaningfully.

Teaching that fosters working theory development involves dilemmas. Responding to working theories involves issues of building conceptual knowledge (Hedges, 2014), hijacking the direction and exploration of the working theories (Davis & Peters, 2012), leading or following the child's interest and working theory (Peters & Davis, 2011), and focusing on the process of

developing working theories, or on accurate conceptual outcomes (Hedges & Cooper, 2014a). While these dilemmas remain, Hedges and Cooper (2014) provided some resolution to the dilemmas. They suggested that children's interests and inquiries be foremost in teachers' thinking, underpinned by the notion of funds of knowledge (González et al., 2005). Thus, teachers might be aware of children's deep interests, and choose to engage with working theories that reflect that interest. Understanding the children's deep interests and inquiries could aid teachers' decision making about leading or following the interest and associated working theories. In regards to a focus on process or outcome, the three-fold understanding of working theories as process, outcome, and interpretive framework that I offered in chapter 4 might be helpful. This understanding offers a way to see working theories not as a binary, but as a simultaneous combination of process, outcome, and interpretive framework, therefore removing the dilemma between process and outcome.

Therefore, teaching approaches that foster working theory development are complex and involve multiple dilemmas. However, research has highlighted that understanding the notion of working theories, knowing the children, hearing their working theories, understanding their deep interests and inquiries could lead to meaningful and authentic responses. These understandings are pivotal to this research and have influenced the development of the SLC model which I explain later in this chapter.

Up to this point, I have focused on everyday teaching approaches related to STEM and working theories. The previous research has explored teaching related to working theory development and how to teach STEM but does not bring them together. My research aims to build on this prior research and to investigate teaching approaches that foster children's development of working theories about STEM. My third and final research question is then the following: How might teachers foster and enrich young children's working theories about the STEM domains?

Of particular importance to my research is the notion of understanding, in particular understanding the children, how they learn, what they know, and their interests. These understandings potentially provide a foundation on which meaningful and authentic experiences can be based on, including the setup of the environment, the materials provided, and teacher involvement with the children that provokes, challenges, stimulates, supports, and extends their learning. These understandings form the basis of the SLC model which I explain further in this chapter. Before moving to the model, it is important that I explain one further aspect that the SLC was built on, which is the notion of sustained shared thinking (SST).

The notion of SST focuses on building thinking together between teachers and children as “two or more individuals work together in an intellectual way to solve a problem, clarify a concept, evaluate activities or extend narratives” (Siraj-Blatchford, 2009, p. 147). SST aligns with the development of working theories about STEM because both are about problem solving, conceptual clarification and the extension of understandings. Through SST, teachers work to understand children and build interactions based on that understanding, encouraging clarification of ideas through language (Gjems, 2013). Understanding the children’s interests and goals is therefore critical as is authentic engagement with children and the introduction of information that challenges or supports their thinking. SST is an important basis of the SLC model which I describe next.

The SLC model

As I described in chapter 2, the development of the SLC model has been a highly iterative, deductive-inductive-abductive (Åsvoll, 2014) process. It began with initial thinking at the thesis proposal stage, and was refined throughout the early literature review. As data was generated and analysed, the SLC model was recursively refined. The model, data, and further literature was then brought together resulting in further refinement of the model. As such, I now move on to present and explain the basis of the SLC model, before presenting findings analytically framed by the model.

The SLC model builds on two key notions: the spiral of working theory development model, and SST. As presented in chapter 4, the spiral of working theory development model consists of four elements: understanding, experience, information and making connections. The SLC model is effectively an overlay of this spiral of working theory development model, with elements that represent the teaching approaches that align with the spiral or working theory elements, as per table 6.

Table 6

Alignment between elements of the spiral of working theory development model and shared learning commitments model

Spiral of working theory development model	**Shared learning commitments model**
Understanding	Understanding
Experience	Providing intentional experiences
Information	Making selected information visible
Making connections	Making connections

The SLC model draws on the notion of SST (Siraj-Blatchford et al., 2002; Siraj-Blatchford, 2007, 2009). I have deliberately moved away from the terms ‘sustained’ and ‘thinking’. ‘Sustained’ can be viewed as problematic, indicating a continuous but undefined time period. By substituting ‘commitment’ for ‘sustained’ the model incorporates a teacher’s intention to follow up a child’s inquiry over time, but not necessarily immediately or in one session. The word commitment then poses the question: commitment to what? For my research, it is a commitment to fostering and enriching children’s working theories about STEM. The commitment could also (and likely would) extend to many other areas of learning outside of the scope of this research. I have also substituted ‘learning’ for ‘thinking’ as learning better encompasses the aspects of knowledge, skills, and attitudes, the aspects of working theories. The shared learning commitment model is shown in Figure 13 below.

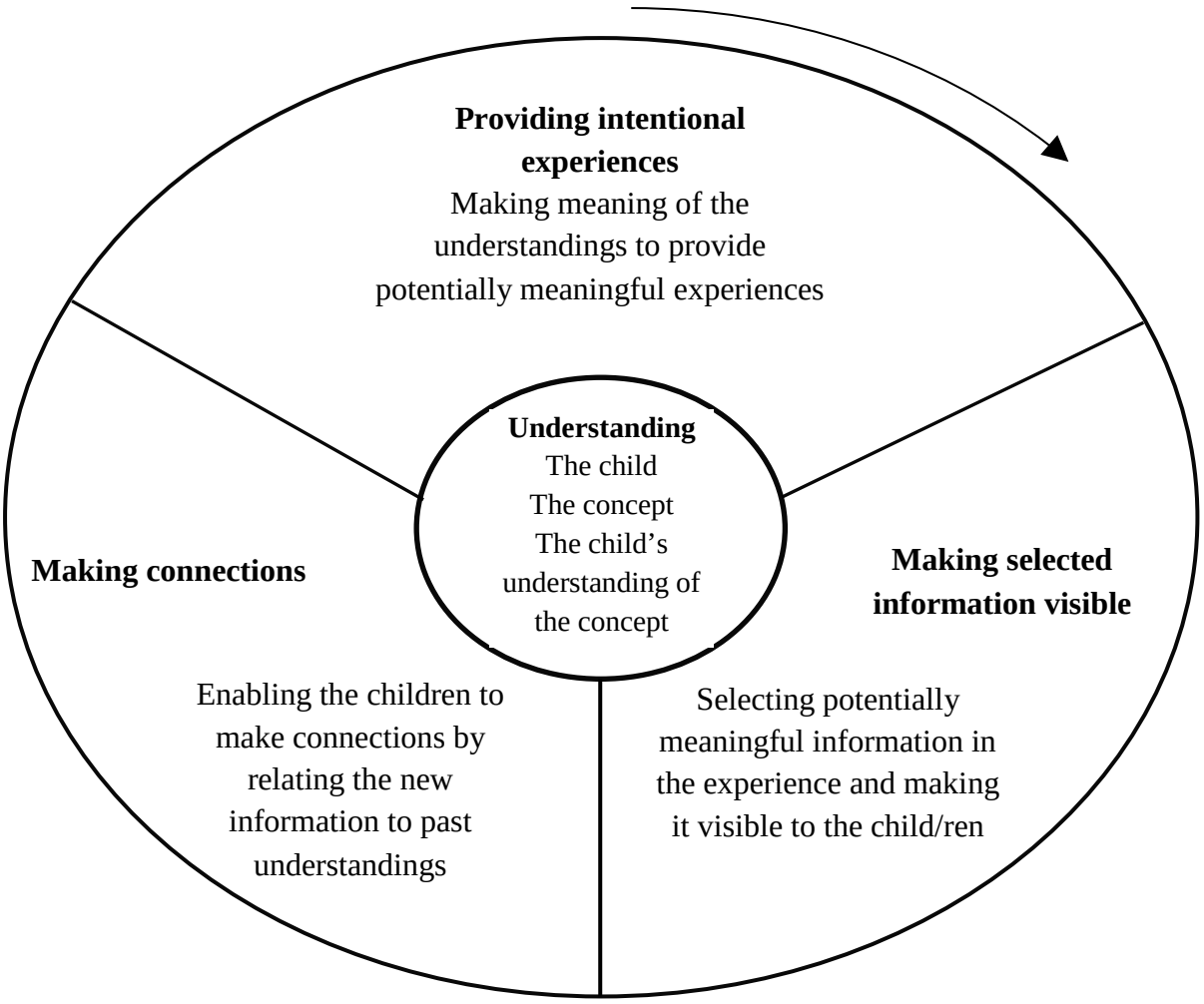


Figure 13. The shared learning commitments (SLC) model.

Consistent with prior literature about teaching that fosters working theory development, the SLC model is based on knowing the children well. Thus, understanding is a central part of teaching STEM and working theories, and forms the centre element of the SLC model. Understanding incorporates three aspects: understanding the child, and in particular their interests, motivations, and prior experiences that have led to their working theories; understanding the children's current/shared/different understanding of the concept; and understanding the concept itself. Understanding the children and the concept provides a basis on which the teacher can then provide intentional experiences, which is the first outer element of the SLC model. The teacher draws on their understanding of the children and their concept/working theories of interest to provide experiences that are potentially meaningful. These experiences may be pre-planned, or in-the-moment, and may vary from setting the environment—for example providing books, providing supporting or challenging materials—to direct engagement—for example short dialogue, reading, to facilitating community visits.

However, an experience on its own does not necessarily lead to information being gained. Each child will likely gain different information from any experience, based on their interests and past experiences (Wells, 1999). This leads to the second outer element: making selected information visible. The teacher's role in this element is to select potentially meaningful information that is available through the experience and make it visible to the children, or draw their conscious awareness to the information. For instance, teachers might summarise, re-word, draw attention to, or clarify the information. The third outer element is making connections. In this element, teachers work together with the child to support connections being formed between the new information gained from the experience and their existing understandings. At times, and based on teachers' understanding of the child, they might reduce the complexity of the information or concept for the child, narrowing contextual boundaries to enable children to apply the new information meaningfully. Teachers might also speculate, ponder, wonder, share their possible thinking, and make those connection obvious to the child. I argue that these elements form a model which represents one way that teachers can foster and enrich children's working theories. I now move on to describe the findings related to research question 3.

Findings

As I described in chapter 2, I have used the SLC model as an analytical framework to analyse the data. Figure 13 shows the final model which involves three outer elements: providing intentional experiences, making selected information from the experiences visible, and making

connections. These three outer elements encompass the central element—understanding—which is the key to teacher decision making. Data analysis highlighted that the complexity of human interactions means that the delineations between the elements of the model are blurred and overlap. Sometimes the interactions fall clearly into one element, however, often they encompass two or more. In an attempt to provide clarity, I therefore begin the findings section of this thesis with a breakdown of the elements of the SLC model, then provide an example of the complete SLC model with all elements interacting together.

Understanding

Analysis of the data indicated that understanding involved two themes: understanding the child/ren, which also includes understanding the children's understanding of the concept, and understanding the concept itself. These themes are highlighted below:

Understanding the child/ren. Understanding the child/ren enabled the teachers to recognise the children's STEM interests, prior experiences, and understandings. A myriad of approaches including observing and listening to the children, talking with family members, talking to other teachers, and documenting children's interests and desires were used.

A consistent message from teachers in both settings was that knowing the children well is essential to forming teaching approaches that foster working theory development. For instance, "to know your children is…critical, it's the base" (Deborah/IN), "you can't blanket all…children. Because they are so incredibly unique and individual" (Joanne/IN). Philosophy statements in both centres reinforced the importance of developing relationships and each child's individuality, for instance: "we value: Respect for each person as an individual – their strengths, abilities, interests, values, culture" (CD/2017).

Because children are unique, they hold different levels of understandings, and differing perspectives to adults. Danielle was explicit about this:

> You have to know the children. I think you need to know where they're at in their levels…the whole way that they…actually think and…see things differently from…an adult perspective. (Danielle/IN)

Danielle's thoughts echoed general teacher thinking that every child is unique, with unique backgrounds, different understandings, and different depths of understandings.

Knowing the child/ren enabled teachers to understand how children learn, as one teacher pointed out:

> [I] think it's such an important question, how you have learnt and what is [sic] your childhood been because that's your experience base. (Deborah/IN)

Later, she added: "if you are familiar with his learning style and thinking style you would give the resources accordingly" (Deborah/IN). Her thinking aligns with literature emphasising the importance of understanding how children learn (Bybee, 2013; English & Moore, 2018; Fleer, 2010).

The importance of understanding the experiences that children had engaged in previously was noted by one teacher who talked about revisiting and building working theories: "It is about the prior experiences that children have with people, places and thing." (Naomi/IN). Her thinking is consistent with the social constructivist approach of the conceptual framework for this research, and aligns with the spiral of working theory development model which I presented in chapter 4. When considered in relation to the model, understanding previous experiences could potentially guide decision making about introducing meaningful new experiences.

Consistent with Hedges and Cooper's (2014) thoughts, the teachers also felt that knowing the child well was important because it provided a base to understand children's deeper interests: "when the child is really interested we can talk about that too" (Sarah/IN)], "it's actually looking at the children's interest…and finding out what they're interested in and where they're headed." (Georgia/IN). At Charleston, the importance of supporting children's interests was prominent in a guiding document titled Indicators of Practice (CD/2017): "The environment is set up with different provocations which enables the children opportunities to extend on their current strengths and interest…Teachers support and extend on children interests and challenge their thinking". However, despite the continual noting of children's general interests such as construction, transportation, Papatūānuku (Māori word for mother earth) and Matariki (Māori new year) in staff meeting minutes at Charleston, no mention was made of any individual interests. Some evidence of individual interests was noted in individual learning stories such as Olivia's interest in the mechanics of leaves (CD/2017). Piccadilly's philosophy stated, "daily activities would be planned around children's interests and development" (CD/2017). To understand children's interests and development, this centre had weekly planning meetings with the children which I explain next.

To understand the children and their interests, the teachers at both centres used a variety of approaches. Piccadilly placed significant importance on weekly planning meetings which a teacher facilitated with the children. In these meetings, each child was given time to let the teacher and the group know what they were interested in, what they wanted to explore about the interest, and when they wanted to do it. Teachers documented these meetings in the form of a mind map and displayed them on the centre notice boards.

The importance of observation was emphasised, consistent with the literature reviewed earlier which highlighted the importance of teachers stepping back and observing the children closely (Bybee, 2013; English & Moore, 2018; Kelly-Ware, 2018). The teachers noted: "observing, a lot of observation, a lot of talking, a lot of like sitting down at their level and finding out what they're interested in and where they're headed" (Georgia/IN), and "we don't respond instantly" (Nerida/FG1), "we don't want to rush in and yea, just trample" (Naomi/FG2), "just observe what's going on. It's your best tool. It's gonna give you the most information about that child." (Joanne/IN). The teachers also noted the complexity involved in understanding their children, drawing on the importance of reflection to guide their approaches: "And do we get it right? Do I get it right all the time? No, definitely not. And that's when we come back to reflections. So you're always reflecting on your practice" (Danielle/IN).

Teachers noted the importance of asking questions, and listening: "Where was she at that point, what was her hypothesis? I can only understand that if I ask them those provoking questions." (Georgia/IN). Questions were not just related to ascertaining the child's knowledge, but also to find out about previous experiences that led to that knowledge: "how do you know? Where did you learn that?...have you done it at home too?" (Sarah/VD). However, teachers also noted that dialogue could be problematic: "I see [a] teacher's role [as] really really critical [about] having conversations. But not all the time, not all the time! Too much talking" (Deborah/IN). This indicates that to understand children, teachers were aware that asking some questions was required, but that observation may be less intrusive.

Teachers shared their understandings of the children together, and asked family members about the children to deepen their understanding of the children. For instance, as a teacher—Georgia—made playdough with Mia, she asked her grandmother about Mia's baking experiences in the home. This discussion helped Georgia to understand that Mia was involved in many baking experiences, enabling Georgia to see Mia as a young expert. The video

observations showed that Georgia's interactions with Mia related to baking then changed as she gave Mia more responsibility in the process of making the playdough.

Both centres highlighted the importance of teachers collaborating together to build the understanding of the children: "while we are working we talk, it's just professional dialogue all the time" (Deborah/IN), "[we notice] that strong interest and then we further strengthen that we discuss that in our meeting" (Deborah/IN). Danielle shared with the other teachers about her experience with the children while castle building, sharing her part in the interaction, the children's thinking and actions to which the teachers offered their input. (Danielle/VD).

Understanding the concepts. All teachers hold some subject knowledge. However, given the complexity of teaching in early childhood, teachers cannot hold in-depth subject knowledge about every topic or domain that might arise. The teachers all appeared comfortable about their subject knowledge, preferring to learn alongside the children: "it's not about giving answers. And that's what I'm quite strongly on that about the working theories it's about us supporting them and learning and investigating together." (Danielle/IN).

Teachers' views about understanding the STEM related concepts that children were interested in centred around three main themes. First, that each teacher brings a diverse range of knowledge, understanding, and expertise that can be drawn on by other teachers. Second, that information communication technology (ICT), in the form of devices and accessibility to the internet, enables teachers to bring subject knowledge into an experience. Third, that children and teachers can learn together. I expand on these themes below.

The first theme, that every teacher has diverse knowledge, was summed up by two teachers, the first who said, "everyone knows about something. And everyone doesn't know about everything." (Deborah/IN). And the second who said, "so we work as a village together" (Danielle/FG1). Teachers noted the critical role that the teaching team provides in subject knowledge: "I go to different teachers and ask their knowledge about that particular, whatever the query is" (Deborah/IN). She shared the specific example where she had been swimming with a child who had been interested in the techniques fish used to swim and in particular, stingrays. Another teacher shared that she had knowledge about stingrays, so the teachers worked together with the child to explore how stingrays and other fish swim (Deborah/FG1). Similarly, Sarah shared the importance of the collective knowledge that multiple teachers bring:

> That's where perhaps the team has its role. Like there are certain aspect[s] of science and technology I may not know, but [another teacher] and [another teacher] might be better off. And I think that's why we have meeting[s] and we discuss what we are doing, and so it's not only we learn with children but also we learn from our colleagues. (Sarah/FG2)

Georgia also noted the importance of drawing on other teachers' expertise in finding out information: "and we ask each other, like I ask somebody we ask each other like I've been searching for this for ages online and I just can't get this can you please help me." (Georgia/FG1).

The second theme was the role of ICT. Teachers acknowledged the importance of ICT when following children's interests in areas where they held little subject knowledge:

> I think we are very lucky in that we are in tech world now. So, when we come here and we tell them, I don't know, let's find out, and we find out together. We've got tools and we try to do that. (Deborah/IN)

At times, the use of ICT was in the moment: "we checked that out on technologies" (Deborah/FG1), "we thought ok let's go and research and find out from google" (Deborah/FG2). At other times, ICT was used to communicate with experts for information: "we have emailed [the] museum [be]cause we were not quite sure what it was and then we get the answers" (Deborah/IN). Similarly, Joanne used her mobile phone to perform a google search for information about animals when children were discussing which animals swim (Joanne/VD). Nerida too checked her information was correct when talking with children about plants by looking up information using a computer tablet. Georgia too used a computer tablet to find informational videos about stars when discussing the shape of stars with children. Joanne noted that using the internet to research was important when done together with the children, and that it was important to teach children how to sift through, and decide on the validity of the information provided (Joanne/IN). She talked about children using ICT to do their own research later in life: "I don't know what the answer is, but I know probably I can get it from…this thing here [her phone]. And that's what they're going to be doing." (Joanne/IN). Danielle noted that young children already knew to ask her to search for information using ICT: "we go on the internet because our young ones say YouTube, google, they'll tell us, so we get the iPads out, and we work with our children." (Danielle/FG1).

Analysis of the data did not indicate that teaching and learning opportunities were missed because of a lack of teacher subject knowledge. However, as I explained in chapter 2, one of the factors influencing my decisions about when to generate data focused on interactions between teachers and children. I acknowledge that there may have been many potential opportunities for STEM related teaching and learning to occur which were not taken up by the teachers due to insufficient subject knowledge. However, as this was not the focus of the research, I did not investigate potential but missed opportunities.

The third theme was that teachers and children can learn together. This theme is closely related to the first and second themes. Because teachers cannot know everything about everything, an approach they used was to learn together with the children: "we tell them we don't know, we need to find out together" (Danielle/FG1), "it is about us admitting oh well actually I don't know, I actually don't know the answer to that but…let's be on that path together." (Naomi/IN). This approach may have addressed the nature of working theories as process and outcome as the teachers modelled how to find the information, how to assess its validity, and gained information. For example, when investigating the shape of stars, Georgia searched on the internet for information, finding the NASA website and sharing with the children:

> When the starlight passes through the earth's atmosphere, the air makes the light rays travel at different speeds, so the stars appear to be twinkle, but the stars look like the shape of a sun. I didn't know that! and this is from NASA! (Georgia/VD)

A child asked "Nasa?", Georgia replied:

> Nasa is the people who are like experts in the space so they know what they are talking about. (Georgia/VD)

Therefore, teachers and children were involved in learning together. Teachers worked with the children to understand the concept, and while doing so, modelled one way to find the information, while also highlighting the validity of the source of information.

The boundaries between the three themes are blurred and overlapping. Often, more than one theme would be used to understand the concept, for instance through teachers talking to each other in the moment of teaching and learning. The teachers would then learn from each other, either in sharing information, or suggesting ways to find the information. Sarah summed up the blurred boundaries: "I think that's why we have meeting[s] and we discuss what we are doing, and so it's not only [that] we learn with children but also we learn from our colleagues, and

then we research…with our children." (Sarah/FG2). All three themes then occurred simultaneously as teachers worked to understand the concept that children were interested in.

The findings from the three themes suggest that teachers held positive attitudes towards learning about STEM together with the children. The teachers recognised that they did not hold deep subject knowledge about many areas related to STEM, but did not view this negatively. Instead, they drew on the knowledge of each other, and researched the information, often with the children. The findings also highlight the importance for teachers at both centres of knowing, and therefore understanding the individual children. For teachers it was more important to understand the child, what they are interested in and how they learn, than to hold in-depth subject knowledge about STEM.

By knowing the child/ren, the teachers formed understandings about the child/ren. These understandings enabled the teachers to recognise the children's interests, prior experiences, and ways of learning. Knowledge of the concept was still needed in some form, even if only basic, as this provided a degree of understanding, which when combined with the understanding of the child provided the foundation for the three outer elements of the SLC model which I explain next.

Providing intentional experiences

In short, this element of the SLC model is about teachers drawing on their understandings of children, and the concepts they are interested in, to provide experiences that are potentially meaningful to the children. By understanding the children's interests and prior experiences, new experiences might provide information that is relevant and significant to the children.

Teachers noted the importance of providing meaningful experiences for the children, for example:

> Learning is about real-life experiences. Real life experiences give so much better understanding. Like going to see a digger at work, and multiple times. And now do a digger puzzle and it is so real and meaningful. (Deborah/FG1)

Teachers also noted that experiences should be based around children's interests: "it's always on their interest and then we're there to challenge that interest, to give them different experiences to develop." (Danielle/IN).

The teaching approaches varied between setting up and supporting children's learning through the provisions of the centre environment, to being intently engaged alongside the children as working theories were developed, to facilitating the experience. For example, Danielle noticed many children had an ongoing interest in construction, particularly with the wooden blocks, perhaps inspired by the neighbouring construction site. She talked about introducing plastic cups and wooden tubes into the wooden block area to add complexity and new possibilities for the children's building, then observing what they did. Interestingly, the children at first only took the cups to the water fountain to drink from. Danielle commented: "they actually did have to observe me to see how to play and then they've gone off and they've made amazing construction and actually more and more construction's been happening in our block area." She added, "they made this big castle and they said the tubes are the water tanks to collect the water." (Danielle/FG1). Provision of new materials only was not enough for the children to use the cups in their building. Facilitation and intent engagement in building and modelling the use of the cups was necessary at first.

Similarly, in the experience about making jelly described in chapter 4, the teaching approaches shifted between providing materials/setting the environment, intent engagement, and facilitation. In this instance, Georgia (a teacher) knew that some children had an interest in baking and baked at home. In particular, Rebecca (a child) had shown a sustained interest in baking over her time at kindergarten, which the teachers had observed and discussed. Georgia placed recipes and cupcake wrappers beside the playdough, but did not stay at the playdough table. Many children, including Rebecca, spent time at the playdough table making cupcakes and looking at the recipes. Later, Rebecca showed Georgia her playdough cupcake, and asked if they could bake together. After looking through a recipe book together, Rebecca, Georgia and some other children made jelly together, learning about the process, sharing their knowledge and working theories, and developing working theories about jelly crystals and dissolving in liquids (Georgia/VD).

The same teacher highlighted the importance of engaging in current interests, drawing on prior experiences and providing potentially meaningful experiences when discussing the shape of stars with a group of children. Again, this teaching and learning experience moved between providing materials/setting the environment, to facilitating, to intent engagement: Following a trip to the local observatory, the teachers set out many activities related to stars and Matariki. For example, over two weeks, the children had baked star-shaped biscuits with the teachers, and drawn constellations onto paper which they then poked holes in and wrapped over the end

of tubes. Looking through the tubes enabled the children to see the stars of the constellations. Building on this interest, and after observing a group of children involved in making stars at the playdough table, Georgia chose to join them (Georgia/VD). One child made a moon, prompting conversation about the cartoon character 'Mr Moon' who had been at the observatory. Georgia shared that Mr Moon was round, and that she had noticed that the stars at the observatory were round too, prompting much debate with the children who were adamant that stars were star-shaped. Georgia then showed the children the NASA video about stars which I described previously in the understandings section of this chapter. Georgia suggested that the song twinkle twinkle little star should be changed to twinkle twinkle little circle. This caused great dissensus, resulting in the group of children singing twinkle twinkle little star loudly, seemingly as a protest and to show they still thought stars were in fact star-shaped. This example demonstrates that Georgia understood the children's interest, prior experience, and their working theories. She intentionally engaged in a meaningful experience based on these understandings and while the children's working theories did not seem to change immediately, the following day, a child told Georgia, "but do you know, it's twinkle twinkle little circle and they are circles in the sky" (Georgia/IN).

Georgia later summed up her thinking, showing the influence that understanding children deeply has on providing experiences:

> It's actually looking at the children's interest and…a lot of observation, a lot of talking, a lot of like sitting down at their level and finding out what they're interested in and where they're headed. And that's where you find out…your what next…and that's where you put something else out there to provoke their thinking. And that's when you bring other stuff in. (Georgia/IN)

To summarise, providing intentional experiences was highly dependent on the teacher's understanding of the children. Within the provision of experiences, the teaching approaches were a mixture of providing materials or setting the environment; facilitating an experience; and being intently involved in the experience with the children. The interactive and blurred nature of the delineations between the understanding and experience elements was highlighted by the teachers drawing on their understandings of the child/ren to provide potentially meaningful experiences. At the same time, the provision of the experiences deepened the teachers' understanding about the child. Much information was available in these experiences for the child/ren. The information available in an experience was not always noticed by the

children. This leads to the third element which is about the teachers' roles in making the information in the experiences visible to the children, which I discuss next.

Making selected information visible

In short, this element is about teaching approaches that make selected information during an experience visible to the children. It is about working with children to make information obvious, to make sense of the experience so children might gain and recognise information that can come from it.

The importance of making information visible and accessible to children was indicated in my field notes during a trip to the local observatory. Danielle (a teacher at Charleston) talked to the accompanying parents before a trip to the local observatory: "[Danielle] encouraged the parents: when you're out in the room with your children, get involved…Talk about what you see and ask them questions." (FN, 15.06.17). The field notes also recorded that later during the field trip, when a live demonstration of water bottle rockets was being shown, the presenter "shared some technical information, but it is hard to see if that made any sense with the children"…"The teacher [Danielle] asked how does this happen and why? (about the rockets) and I wonder if this helped the children engage" (FN, 15.06.17). I noted that the experience had begun with technical information that children were not able to engage with, to an experience where the presenter explained the information at a more fundamental level which the young children could make sense of. The children then became more engaged, responding to the presenter and asking questions. Again, this example shows the importance of understanding the children and the concepts. Because Danielle understood the children, their interests and their levels of understanding, she prompted the presenter to share the information at a level the children could engage with.

When engaging intently with the children, and then restating their ideas, teachers added legitimacy to the children's thinking and made their thinking visible to the other children. For example, during a children's meeting at Piccadilly, a group of children were discussing how they could transport some bicycles to a park. Two teachers—Sarah and Joanne—were facilitating the meeting. The children had decided they could hold onto the bicycles in the van during the trip which Sarah re-stated, "you mean how we can park some bikes beside you while you're sitting in the van so you can hold it." (Sarah/VD). Joanne asked the children what would happen if the brakes were applied suddenly. But the children did not understand her question. She asked again, but it was not until Sarah re-stated the question and added a physical action

that the children understood: “but sometime[s] when the van sudden[ly] stop[s] and the force just come[s] like this” [clapping once to demonstrate] (Sarah/VD). After thinking about this for a while, a child responded, “the bikes will just push off, the bikes wheels will just push and then [he crashes his hand into the mat] fall and break” (Thomas/VD). During the ongoing discussion, as the working theories became more complex, the children decided that they could place the bicycles under their seats and wedge wood in front of them to stop them moving. Again, Sarah made this information available to all the children: “you think the wood to support the bikes, so the bikes won’t move, is that what you what you are thinking?” (Sarah/VD). By summarising the ideas of the children, Sarah made their working theories visible for other children. This enabled the child who spoke to hear his own working theories out loud, to receive feedback on his ideas and to make his working theories visible for other children to build on. Joanne had been passing by when she made her first comment, and had not been intently engaged in the conversation which may have led to the children’s earlier confusion. Sarah had been intently engaged in the ongoing discussion, understood where the children’s thinking was, how they had formed their understanding, and how best to respond.

The importance of being intently engaged in an experience was also displayed by Danielle who was sitting on the floor with children as they built an elaborate castle using small wooden blocks (also see chapter 4 which describes this vignette). Danielle asked, “should we get some rulers and see how high it is?” (Danielle/VD). This small sentence introduced two pieces of information. First, height was involved as the castle was getting tall, and could be measured. Second, a ruler is a tool for measuring height. Once the ruler was in place against the castle, Danielle added more information: “see the ruler’s got numbers on it and that goes up to 30 centimetres so let’s see how high that is...Can you see how high?” (Danielle/VD). Danielle was building on what the children already understood by adding numbers and units. Shortly after, she said “it’s not as high as that is it? See it stops there. Can you build it as high as two rulers?” (Danielle/VD). Danielle continued to make information visible about the ruler, the markings on the ruler and the comparison to the construction. Later as the construction continued, together Danielle and a child measured the height again, this time using two rulers placed end on end. Danielle stated, “[the child] said that’s still not as big as the rulers, it’s still not as tall is it, see he’s put, so put it beside it…let’s have a look, two rulers, it’s nearly” (Danielle/VD). She continued to voice her observations, sharing the information about height and suggesting comparisons between construction and ruler. As she did this, the children were likely refining their working theories as they continued to experiment and measure, making connections

between their existing understandings, the information that Danielle pointed out, and their physical experience of building and measuring.

One way that teachers made information visible was by voicing their own thinking. This was done both in the moment, and retrospectively, and sometimes both in the same experience. At times, this was done tentatively and uncertainly, at other times knowledgeably. For instance, when working out if stars were star-shaped or circular, Georgia said:

> I was wondering, when we went to Stardome we saw Mr Moon…he was in a circle but when he showed us the star he looked like a circle. I was wondering if stars, the shape of a star is like that or a circle? (Georgia/VD)

In this short conversation, Georgia revisited the earlier experience of the trip to the observatory and made information visible that seemed to have been overlooked by the children. She sought out the children's thinking and understanding. Shortly after, Georgia re-voiced information that was gained as she and the children watched a video about stars:

> So it is not like that! It looks like the sun. [A child nodded slightly]. We've got it. So when we look up in the sky it's so, so far away, it kind of twinkles so it looks like the shape of a star. (Georgia/VD)

Joanne summed up making selected information explicit: "I think it's important through language [to] articulate what they're seeing" (Joanne/IN). Her thoughts are consistent with the actions of Sarah who demonstrated making information explicit when she engaged with some children who were making domino tracks using wooden blocks placed on their ends. Sarah had previously asked the children how they knew the distance to place the blocks apart but had received little response. It appeared that they had an implicit understanding of the distance to leave between the blocks, perhaps through previous trial and error. Shortly afterwards, Sarah made the information explicit about distances and possible consequences: "it seems that the blocks [are] getting closer and closer to each other. It will be interesting to watch this one. There is a big gap here." (Sarah/VD). While the children did not immediately respond, their facial expressions indicated that they were thinking about her comment. As the tracks became increasingly more complex, the children placed more emphasis on the distance between the blocks: "[Frank] brings two more blocks over and places them too far apart, so he can see immediately that there is a problem and places them closer together." (Frank/VD). As the children introduced corners into their track they now focused on distance and alignment. Frank looked at the positions of two blocks and said, "that might not work" (Frank/VD). Sarah

questioned him about why he thought so, but received no answer. She then stated, “I can’t wait to see the one that [Frank] says it may not work. See if it’s gonna work or not.” (Sarah/VD), making his thinking and statement visible to the other children. The domino track did not completely work, stopping at the point Frank had indicated. Sarah asked, “I wonder why they landed like that?” (Sarah/VD) voicing her observation and making the information clear: something had gone wrong. A child replied, “because they were not ready” (Thomas/VD) perhaps referring to the distance and alignment between the blocks not being correct. The children rebuilt the track, and this time at a sharp corner, Frank repositioned the blocks forming the corner to a place alongside the track to test them. Seeing that they worked he re-placed them into the track. The episode shows that the children did not always respond immediately to the information that had been made visible. However, in this case, after time there was a response—the track was re-made to include the new information. This shows that making information visible might prompt children to make connections between their current understandings and the new information even if that is not immediately seen.

To summarise, the general teaching approach that made selected information visible was being intently engaged in the experience with the children. By doing this, and through understanding the child, their prior experiences, their understandings and their interests, teachers were then able to make informed decisions about selecting the information to make visible by restating others’ thinking, making suggestions and asking questions.

Making connections

Making connections is the next element of the shared learning commitment model. For the purpose of this research, making connections is about the teaching approaches that potentially enabled children to make sense of the new information in light of their already held understandings. It flows from understanding the child and the concept, providing intentional experiences, and making selected information visible.

One of the teaching approaches used to stimulate connections was prompting the children to think. When a child noticed that water which was poured onto the sand in the sandpit seemed to disappear, a teacher did not provide direct answers. Instead she prompted him to make connections between the information and his understandings: “I was asking him you know what’s happening, what do you think’s happening. So, I was really getting him to think and investigate it.” (Danielle/IN). Together, the child and teacher then carried out further investigations. When talking about deepening and extending the children’s thinking the teacher

noted the importance of asking questions especially questions that began with how or why, stimulating investigation and giving them ideas that they could then make connections about, and providing plenty of time: “we provoke them, we let them think, and in that thinking process, their brain is ticking.” (Danielle/IN). This approach likely prompted the child to make connections, and to develop new, or refine existing working theories about the water and sand.

Sarah demonstrated a similar approach when two children were building a domino track and knocked it over. At a tight curve, where some blocks didn’t fall over, Sarah asked, “why [did] that one went that way and that [other] one went that way?” (Sarah/VD). Then, when talking about a nearby block, she added, “but it still got knocked down, [pause] that’s interesting.” (Sarah/VD). Sarah did not provide an answer for the children. Instead, she provoked the children to think by making selected information clear from the experience—some blocks did not fall over—and at the same time asked the children to connect what had happened with their existing understandings and expectations. The children did not have an immediate response. However, later that day, when building another track, the same problem occurred—at a bend, one of the blocks did not fall over. When asked about this, Frank said, “because it turned” (Frank/VD), suggesting the preceding block had been out of alignment and had not knocked the following block down. Later still, Sarah asked, “I wonder what will happen” (Sarah/VD) and Frank responded, “cos…if this one hits this one [pointing to two adjacent blocks] that one will just go meeeeam boom” (Frank/VD). He showed how it would be if it was twisted and misaligned, “so I think that won’t work.” (Frank/VD), and he realigned the block. The episode shows the importance of repeating and revisiting experiences and that working theories might not develop instantaneously, but might need time to incubate, cultivate and develop.

Teachers mentioned the importance of context, especially that experiences and information must be relatable. In particular, they talked about using concrete concepts that the children could identify with. For instance, a teacher shared that she might talk about the planet Pluto, which children have never seen and may be too abstract, whereas discussing the sun is much more relatable as children see and feel it every day. As described in chapter 4, when Sarah (a teacher) was making a recipe with children, the children had decided that one teaspoon of baking powder was required for three bananas. Sarah asked them how many teaspoons would then be needed for six bananas. The children could not make the mathematical connection until Sarah separated the bananas into two piles of three each, and placed one teaspoon on each. In this instance, for children to make connections, a concrete visual model was required.

However, the data indicated that using a combination of concrete concepts and imagination might be useful in enriching and broadening working theories. The instance where the children were deciding how to safely transport the bikes in the van highlights this. The teachers asked the children to think through an abstract scenario—what if the van stops suddenly. In this case, the children could not understand the teachers' question until she used hand movements to indicate the forces that would be acting on the bikes. Once she did that, the children were able to make connections and understand the concept. Still, the children needed to use their imagination to connect the hand movement with the vehicle movement. Perhaps then, teaching approaches that provide a mixture of abstract and concrete evidence are required.

This approach also occurred during the soccer game organisation when two children and a teacher were working out how to put numbers on children's shirts. The teacher asked Thomas, "how are you going to put number 4 on your shirt?" (Sarah/VD). Another child responded, "you could draw it" (Elizabeth/VD), prompting Thomas to twist around, trying to look at his back. Thomas announced, "but what if I can't see? And do the wrong thing?" (Thomas/VD), assuming that he would be writing the number on his back while still wearing the shirt. A little later, Thomas said, "I could take my t-shirt off and then write it" (Thomas/VD) showing that he had continued to consider the problem and found a solution. The teacher then suggested they write the numbers on paper, and the issue became how to attach the paper to their t-shirts. The teacher suggested pinning it on, however Thomas became worried that he would be stabbed by the pins. After thinking about it, he suggested, "I think sellotape [TM]" and Frank replied, "what about glue?" (Frank/VD). Again, Thomas made connections between this new information and what he already knew, saying, "but if you rip it off my back, if you rip it off my back, it'll, it will rip my t-shirt!" (Thomas/VD). They decided on sticky-tape, wrote their numbers on paper, and with great difficulty attached the paper with sticky-tape to their backs. This is a short part of a long excerpt where the children then tested the sticky-tape by playing outside to see if it held, then trialled glue, where they discussed the correct glue required, briefly talked about sewing the numbers on, and finally used stickers. The teacher's role in this experience was largely as facilitator, however she was intently engaged in the process. Importantly, she did not provide definitive answers to the issues the children were thinking through. She provided the children with time, where neither teacher nor child talked as both appeared to be thinking. She also provided time for the teacher and children to discuss together, problem solve, experiment, make connections, and form new understandings about the process

of working through the problem until they had a solution they were satisfied with. Thus, working theories were formed, refined, tested and further refined.

The making connections element involved teaching approaches such as not providing specific answers, prompting the children to think, asking how and why questions, providing time for the children's theorising to incubate, and mixing concrete and abstract concepts and examples. This element is one of three outer elements. As I have explained, the SLC is a combination of all three elements based on the central element of understanding. I now move on from the discrete elements to the complete model.

A combination of multiple elements

As mentioned earlier, the delineation between the teaching approaches involved in fostering and enriching children's working theories are complex. The central element of understanding is crucial as it enables teachers to draw on their pedagogical and subject knowledge to move through the three outer elements of providing intentional experiences, making selected information visible and making connections. Furthermore, making teaching more complex, the delineations between the elements are blurred. The vignette about making jelly highlights the complexity of the teaching approaches.

Early in the jelly-making experience, Georgia (a teacher) asked Rebecca (a child) how to make jelly. Rebecca shared her working theory, likely based on past experience at home: "um you can, you puts some fruit in and then put a drink in and then put it in the fridge so it gets cold and then you can eat it" (Rebecca/VD). Rebecca likely equated the concept of a drink as being the crystals from a sachet of fruit drink with the jelly crystals. The teachers built on her working theory, making the connection between the dry jelly crystals and sand for the children: "you can feel it and touch it, it feels like sand" (Georgia/VD), and asking if they could add sand to water to make jelly. As the hot water was added, the teacher asked, "what do you think Rebecca? Can it turn into jelly? yes? Are you sure? It just looks like powder to me." (Georgia/VD). She then asked, "should we try to put sand and water in the fridge?" (Georgia/VD) to which Rebecca and the other children were adamant that it would not work, likely based on their observations of sand and water in the sandpit.

The concept of dissolving was introduced as the jelly-making continued, first without explanation: "stir thoroughly until it dissolves" (Georgia/VD). She then explained the amount of hot water needed adding, "stir thoroughly until it is dissolved. Are we doing that?...yea cos

it says it in the instructions, stir thoroughly until dissolved, to make sure it is." (Georgia/VD). She then said, "we cannot put this in the fridge unless, until it is stirred thoroughly." (Georgia/VD), sharing a connection between stirring, dissolving and readiness of the mixture, although not sharing explicit information about what dissolving meant. As the mixture dissolved the teacher then asked the children what had happened to the jelly crystals. Rebecca responded that it had "gone [pause] gone boiled." (Rebecca/VD), possibly connecting the requirement of hot water with dissolving.

Another child arrived at the jelly-making experience with a magnifying glass. A different teacher—Danielle—said to her, "oh, you've got your magnifying glass just to make sure it's all been stirred, all the crystals have been stirred?" (Danielle/VD). She added, "yes, cos you have to look and make sure there's no lumps, have a look through…the magnifying glass…have a look and make sure there's no crystals at the back." (Danielle/VD). As the child looked through the magnifying glass, Danielle asked, "is it looking good? Can you see the crystals?" (Danielle/VD). The child shook her head and Rebecca said the crystals are "in the back" (Rebecca/VD). Danielle took the magnifying glass, saying "let me have a look with my eye. Ooh I don't see any crystal, there are no hard bits down the bottom." (Danielle/VD). She then shared, "crystals is like this" [pointing to some spilled on the table] "and it's down the bottom and it's lumpy. So have a look, see…Can you see?" (Danielle/VD). The teacher then connected no lumps with readiness, saying "I think this one's ready, do you think that one's ready now? There's no crystals?" (Danielle/VD). Finally, they moved to the notion of dissolving again as Danielle asked, "were the crystals dissolved?" (Danielle/VD). The children replied that they were, to which Danielle responded, "so what did the water do with the crystal?" (Danielle/VD). Rebecca replied, "boil it." (Rebecca/VD). Danielle then said, "The crystal was like this", showing some crystals still on the table, "and what did the water do? it went into a liquid." (Danielle/VD). Rebecca replied, "when [pause] a liquid?" (Rebecca/VD) in a confused tone.

During this experience, Rebecca's understanding of dissolving shifted from the crystals being "in the back" to they are "gone" to "gone boiled" to the water "boil it [the crystals]" and at the end she stated "when [pause] a liquid?" showing she was in a state of perplexity, but thinking hard and trying to make the connections between what she had seen and what she knew. The teacher then suggested they investigate materials that change state from solids to liquids. Unfortunately, neither Rebecca's later working theories about dissolving nor further experiments were observed in this research.

This experience drew on the teachers' understanding of Rebecca. The teachers had taught Rebecca for two years. They already knew she baked at home and loved to bake at the centre. Georgia said, "I know she loves cooking a lot and she's always at the playdough table or in the sandpit cooking" (Georgia/IN). They understood that an experience such as this would be meaningful for Rebecca, and that she would be motivated and engaged. Georgia then negotiated with Rebecca and provided an intentional, and potentially meaningful experience in response to her understanding of Rebecca. The negotiation of this was a lengthy process as the teacher and Rebecca decided together about what they should make.

The following section repeats some of the vignette by focusing on the teachers' words. First, I highlight the information that the teachers selected to make visible to the children. Next, I focus on the ways that teachers helped children to make connections. The focus of this section is about the concept of dissolving, introduced simply at first, and becoming increasingly more complex:

"all the crystals have been stirred?"

Then, "stir until dissolved"

then, "you have to make sure there's no lumps"

then, "make sure there's no crystals in the back"

then, "I don't see any crystal, there are no hard bits down the bottom"

then, "crystals is like this [pointing to some] and it's down the bottom and it's lumpy"

then, "it went into a liquid"

and finally, they touched on changes in state by saying they could "have a look and see what other things go from a solid to a liquid or a liquid to a solid"

The teachers worked with the children to form connections between what they already understood and the new information. This can be seen in the following:

"have a look, see…Can you see?"

"Do you think that one's ready now? There's no crystals?"

Asking where the crystals went: "where's it gone? What happened to it?"

Prompting for further thinking, “gone where?”, “gone boiled?”, “what’s happened to it when we put water in it?”, “so what did the water do with the crystal?”.

Together, through understanding Rebecca, and her interest in baking, Georgia negotiated with Rebecca to provide an intentional experience that drew on her understandings. As they made jelly, Georgia and Danielle drew on their understanding of Rebecca and of the concepts involved in jelly-making to make selected information available. The teachers then worked with Rebecca to help her make new connections between her old understandings and the new information to develop and enrich her working theories about jelly-making, and the process of dissolving.

When considering the notion of dissolving, the teacher interactions with the children in this experience might be considered haphazard. However, when viewed in light of the teachers’ philosophies that they did not want to provide answers, but instead encourage investigations, then the teaching approaches make sense. Instead of providing a definition of dissolving, the teachers encouraged the children to consider connections between jelly crystals and sand, and implicitly encouraged the children to carry out a scientific experiment into dissolving. The teachers’ thinking aligns with the spiral of working theory development model where the aim is not to reach a point of conceptual accuracy, but instead is to enrich children’s working theories.

In keeping with the conceptual framework of this research which brings together social constructivist and sociocultural perspectives underpinned by an interpretivist paradigm, it is important to note that while the description I have provided focuses on one child, many children were involved throughout the experience. The jelly-making experience is therefore framed by social interactions between teachers, children, and their peers, carried out in the specific context of Charleston ECE centre. A sociocultural environment was then provided that weaved together the culture of the centre, and the cultures of the children and teachers. The individual children developed their own working theories about jelly-making and dissolving, through social interactions within the sociocultural environment.

The findings show that teachers’ understandings of children are critical to fostering and enriching working theories. A deep understanding of children provided a foundation on which experiences, information, and connections were built. To understand children, teachers observed, listened, talked among themselves, with the children’s family and with the children. Using these understandings, the teachers then provided intentional experiences. The teachers

were involved in various ways in the experiences, from setting up the environment and leaving the children to interact with it, to facilitating the experience, to intently engaging with the children in the experience. During the experiences, teachers made information visible to the children, not providing direct answers, but re-stating information, and making suggestions. The teachers then worked with the children to make connections, prompting the children to think, providing time for thinking to occur, and mixing concrete and abstract concepts and possibilities.

Discussion

As I explained earlier in this chapter, the SLC model draws heavily on the spiral of working theory development model. Both are iterative, circular models, with four similar elements. The SLC is based on the central element which is understanding. The outer elements then begin with providing intentional experiences, moving in a clockwise direction.

The jelly-making experience described earlier highlights that the SLC model consists of multiple layers. To begin with, the teacher (Georgia) provided an experience based on her understanding of the child. Prior research has identified that understanding children well enables teaching and learning that supports working theory development (Davis & Peters, 2011; Hill, 2015; Kelly et al., 2013). In this case, the jelly-making experience came about from the children undertaking the daily experience of using playdough. The teacher added baking related materials to the playdough table such as recipes and cupcake wrappers, but left the experience open-ended for the children to use as they desired. As Georgia did not involve herself further in the playdough experience, she did not directly engage with the children to make selected information visible or to make connections with them. However, the responsive provision of a provoking environment can be considered a teaching approach where information is held inherently within the objects or materials aligning with a discovery learning approach (Piaget, 1970). Although this perspective does not align with the sociocultural underpinnings of the shared learning commitment, the provision of these materials led to a shared learning commitment where working theories were fostered and enriched.

Rebecca brought her playdough/collage cupcake over to Georgia and this is where the SLC began. Georgia built on her prior understanding of Rebecca as an interested, knowledgeable baker and made an intentional decision to engage with Rebecca in an authentic baking experience. In this chapter, I have focused on the concept of dissolving as an SLC, however

other aspects could equally be considered including the negotiation between teacher and child about making jelly. The blurred delineations of the SLC can be seen in that by providing the jelly-making experience, Georgia was able to understand Rebecca better as she shared her initial working theory about how jelly was made.

Throughout the experience, the teachers selected information about dissolving to make visible. The setup of the environment, and teacher decisions led to a meaningful experience for the children. The teachers engaged with the children to wonder together (Davis & Peters, 2011), added complexity (Hedges, 2011), presented specific information about the jelly crystals dissolving (Lovatt, 2013) within a meaningful context (Hargraves, 2013). This was not a straightforward, linear process, but represents the complexity of supporting the development of children's working theories (Davis & Peters, 2011).

The teachers engaged with the children to make connections between their existing understandings and the new information. Rebecca shared that a drink was needed to make jelly, equating the jelly crystals with flavoured drink sachet crystals. The teachers effectively asked her to make connections between different crystals by showing that jelly crystals and sand looked similar and asking the children if jelly could be made from sand. The teachers also added that hot water and stirring was required, providing a spoon so that the children could watch the dissolving process as they were directly involved in stirring the crystals in the hot water. The teachers reduced the complexity of the dissolving process and introduced new information in small steps, allowing the children to make connections. The key to the element of making connections is that the teacher remained intently engaged with the children as they stirred, and importantly, asked them what was happening. Near the end of the vignette, a teacher specifically asked what had happened to the crystals, prompting the children to make connections between what they knew and what had occurred. As the children did not respond, the teacher answered for them saying it had gone into a liquid. Her response may not have provided enough time for the children to make connections and respond (Davis & Peters, 2011), representing Hedges (2014) thoughts that it is difficult for teachers to know when to feed conceptual knowledge into children's experiences.

Rebecca's understanding about dissolving shifted throughout the experience. She started with little understanding that dissolving was needed for jelly-making, and little understanding about the concept of dissolving. She moved from a basic understanding that the crystals were gone, to including the action of heat (they were boiled), and throughout the experience, stirred the

crystals for a long time. It is likely that her new working theory about jelly-making then included the process of dissolving and that dissolving involved factors of liquid, heat, stirring and time, therefore becoming richer and broader than her original understanding.

Working theories are not just understandings. They are a combination of knowledge, skills and attitudes. Working theories are built through experiences and information. Therefore, in the jelly-making vignette, Rebecca's working theories about jelly-making were more than just the understandings detailed above. They included the sensations of feeling the dry crystals, of watching the dissolving process, of feeling the steam from the boiling water, and tasting and feeling the smoothness of the jelly once it had set.

SLCs are one perspective of teaching approaches that foster and enrich young children's working theories. They are an overlay on the spiral of working theory development model with the elements in the SLC corresponding to the elements in the working theories model. SLCs are likely to be nested, that is many smaller experiences will be provided, information made visible, and connections made within a larger experience where information is made visible and connections made. A key to SLCs is understanding the child well. This is effectively the foundation which enables teachers to build experiences, make information visible, and support connection making. However, understanding is one of the ongoing dynamic elements of the SLC. Through the experiences, information gained, connections made, and understandings that are formed teachers can develop greater understanding of the child/ren.

It is tempting to represent the SLC as a spiral, similar to the spiral of working theories development model. However, at this stage, I do not consider that I have adequate data to make such a representation. I wonder if the SLC model might evolve to show that as a teacher goes through multiple iterations of the SLC, that the central element of understanding becomes larger due to an enriched understanding of the child and the concept. At the same time, I wonder if the outer circle of the model remains the same diameter, effectively representing that the teaching approaches in each element are becoming focused, responsive, and relative to that understanding. However, that is the subject of further research.

Conclusion

The SLC model is a teaching approach that supports the development of young children's working theories. A shared learning commitment is a combination of understanding the child/ren themselves, their working theories, and an understanding of the concepts involved.

Teachers then provide intentional and potentially meaningful experiences based on that understanding; making selected information visible in those experiences; and supporting children to make connections between old/existing understandings and the new information.

The SLC model is not a simple step by step process. The model is intended to be used as an analytic tool in everyday, naturalistic early childhood settings. Teaching and learning in these settings is complex. The elements of the SLC model have blurred boundaries, overlap and interact together. However, I believe a focus on, and implementation of the SLC model by reflective, critical teachers can support young children's working theory development.

The SLC has potential to be applied to further areas of learning. I by no means offer the SLC as a generalised account for all early childhood settings. However, the principle of transferability (Guba & Lincoln, 1989) signifies that teaching approaches and theoretical models in this study could be applicable in other contexts. For this research, I focused on fostering and enriching children's working theories about the STEM domains. While working theories is a New Zealand concept, as I have argued in chapter 1, there are alignments between working theories and thinking, concept development, and knowledge building. These alignments mean that the shared learning commitment model has potential to be used in contexts outside of New Zealand. Furthermore, while I focused on the STEM domains, there is potential for the SLC model to be applied to other learning domains.

As teachers listen, observe closely, develop deep relationships and in-depth understandings of their children they can provide meaningful responses to children's interests, motivations, learning and expectations. The SLC model provides one way that teachers might make their responses intentional and analytical. By using this model, I argue that children will be supported in their learning, as teachers foster and enrich their working theories, and hence their concepts, knowledge, and thinking.

6. Mediation: A theoretical explanation

Introduction

In this chapter I use the theoretical construct of mediation (Vygotsky, 1986) to explain the findings presented in chapters 3-5 that respectively addressed the three research questions. Similar to those chapters, this is not a typical thesis chapter. Because there is not a single literature review chapter in this thesis, the mediation groundwork has not been laid, and therefore is done so in this chapter. Therefore, this chapter begins with an explanation of the construct of mediation in terms of this research. Next, I develop a rationale for mediation being an appropriate underpinning theoretical construct for this study. I then explain and theorise the three supporting research questions through the perspective of mediation. Next, I weave the explanations of the three research questions together to explain how mediation addresses the overarching research question of how might working theories about STEM be developed, fostered and enriched in early childhood settings.

I view mediation as one of many theoretical constructs which could provide a lens to understand how children develop working theories, and how teachers might engage in fostering and enriching working theories. As I alluded to in chapter 1, it was tempting to use a cognitive psychology theoretical perspective. However, mediation aligns better with my conceptual framework, which brings together social constructivist and sociocultural approaches within an interpretivist paradigm. Furthermore, as I noted in chapter 1, sociocultural theories are highlighted in *Te Whāriki*, and mediation has been acknowledged as being a valid lens to interpret the curriculum. As I analysed the data, and theorised the findings, I found that mediation provided valid and in-depth explanations. Therefore, for this research, I have used mediation as an explanatory theoretical lens.

Mediation in this thesis

Mediation is a theoretical construct that has multiple meanings and interpretations (Kozulin, 2018). Therefore, it is important to explain how I view mediation for this research. Mediation originated from Vygotsky's work. His thoughts on mediation varied over time from foregrounding psychological stimuli to making sense and meaning (Wertsch, 2007). His thoughts have been adapted and built on by many scholars. For my research, I have drawn on the work about mediation by Wertsch (1991, 2007), Cole (1996), Daniels (2015), and Kozulin

(2003, 2018) to inform—or perhaps more appropriately to mediate—my understanding of the construct as I explain next.

Mediation is a complex theoretical construct situated within sociocultural theory. At its most general, mediation involves an influence—or mediator—in the interaction between two objects, events, or people (Kozulin, 2018). The mediator is referred to by different terms through the literature. For this thesis, I refer to it as mediating artefact. To best describe my conceptualisation of mediation for this research, in Figure 14, I present the mediational triangle (Cole, 1996) which shows that in essence, a person's action towards, relation to, or understanding of an object can be either mediated or natural (also called unmediated). The subject and object are connected or act on each other in natural ways, and through mediated ways. For this research, I am focusing on the mediated ways that relations, understandings, and actions are developed between object and subject. I explain the terms subject, object and mediating artefact next.

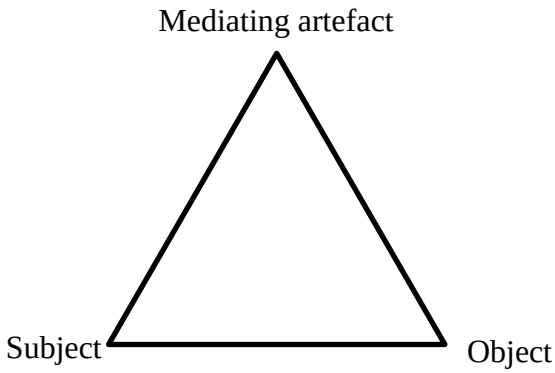


Figure 14. The mediational triangle.

The mediational triangle identifies three aspects: subject, object and mediating artefact. For this research, the subject is the participants of the research, that is the teachers and the children. The object is that which the teacher or child/ren are attempting to make sense of. The object might be purely conceptual (Bereiter, 2002; Daniels, 2015) which therefore encompasses children's working theories as I explain later in this chapter. The object might also be material such as building blocks. However, as Cole (1996) notes, material objects simultaneously have concepts attached and are therefore in the eye of the subject, also imbued with conceptual properties.

The term mediating artefact refers to the signs and tools that function as mediating agents (Wertsch, 1991; Daniels, 2015; Kozulin, 2003). Mediating artefacts enable the transfer of

understandings from the social plane to the individual plane (Wertsch, 2007). For this research, this means that mediating artefacts enable individuals to make sense of new information within the social, cultural, and historical settings that they are living in. I have focused on mediating artefacts as being signs, that is sign systems and psychological tools (Wertsch, 2007), which similar to objects, can be both material and conceptual (Cole, 1996).

To clarify the potential explanation of mediation in ECE settings, I turn to a small excerpt from the jelly-making vignette from chapter 5. A child had approached the jelly-making experience with a magnifying glass. A teacher commented that the child had brought the magnifying glass to make sure the mixture, in particular the crystals were all stirred. The teacher noted that using the magnifying glass would indicate if there were any lumps in the mixture. In the jelly-making experience, the teacher was aware that there had been talk about the jelly crystals dissolving. The mediational triangle can be used to theorise this experience. In this case, the children were the subject, and the object was the concept of dissolving. The mediating artefact was the teacher's words, spoken to help the children make sense of the term dissolving. As I mentioned previously, the notion of mediation is complex, and multiple perspectives can be used. An alternate perspective could be that the subject was the child with the magnifying glass. She might have come seeking specifically to understand what dissolving meant, therefore the concept of dissolving was the object. And she might have purposely brought the magnifying glass with her to aid in her understanding. Therefore, the magnifying glass would then be considered as the mediating artefact. Perhaps then, the mediational triangle forms part of a more complex 3D image of many triangles that combine together that reflect the complexity of teaching and learning.

For this research, I acknowledge, and later use the findings to show that one experience can be viewed through multiple perspectives using the mediational triangle. However, I do not address the complexity of attempting to reconcile these alternate perspectives into one 3D image. That could be investigated in further research. Before I move to the findings, I first explain how mediation relates to each of the three research questions, beginning with teachers' perceptions of STEM.

It is important to explore and justify the alignment between perception and concept in regards to mediating artefacts. Concepts can act as mediating artefacts (Daniels, 2015). Perception is similar to, but not the same as concept. The Oxford online dictionary (Lea & Bradberry, 2020) describes perception as being a belief, an idea, or an image that is held as a result of an

understanding. Whereas, a concept is described as an understanding or belief of what something is. I argue that because concepts lead to understandings which in turn lead to perceptions, then concepts lead to perception. An understanding about something leads to beliefs or images about that same thing. Because concepts can act as mediating artefacts, then perceptions can also act as mediating artefacts. Perceptions of a subject domain can mediate whether or not a person will become involved in exploring that domain. I build on this argument later in this chapter when I explain the findings that addressed research question 1. The next section explains mediation in terms of research questions 2 and 3.

The construct of mediation provides a theoretical perspective of the spiral of knowing model (Wells, 1999). This model led to the spiral of working theory development model which addresses research question 2. In the spiral of knowing, through knowledge building, a learner uses past experiences and information to make sense of new information and experiences (Wells, 1999). The skills of knowledge building can be considered as mediating artefacts, providing the child with the processing know-how to make sense of new information. Furthermore, the child's past experiences and information can also be considered as mediating agents which provide a foundation of understanding to enable connections and sense to be made of the new experiences and information. Mediation therefore provides a theoretical explanation of this model.

Because the spiral of knowing can be viewed from a mediational perspective, and the spiral of working theory development model builds on this model, then the spiral of working theory development can, in turn be viewed through a mediational perspective. Just as the four elements of the spiral of knowing can be considered as mediating artefacts, so too can the four elements of the spiral of working theory development. As I argue further on in this chapter when I explain the findings that address research question 2, working theories in themselves can also be considered as mediating agents.

Teaching approaches, which are the focus of research question 3, can also be viewed through a mediational lens. Teachers have a central role in mediating children's learning (Fleer, 2010). In short, from a teaching approaches perspective, mediation can be thought of as the approaches that a teacher uses to enable children to make sense of their experiences and new information. From the perspective of Cole's mediational triangle, and in keeping with Hedegaard's (2007) thoughts, I view teaching approaches that foster and enrich children's working theories as mediating artefacts. That is, they are the teaching approaches that foster and enrich the

subject's—which in this case is the children's—understanding of the object. As mediating artefacts, teachers might use dialogue, or intentionally provide resources, materials and setup the environment to mediate children's learning. Importantly, for this research, the teacher has a mediating role to not only provide the materials, resources and environmental setup, but to engage with the children to mediate their interactions and understanding of it (Gillespie & Zittoun, 2010). In effect, the teaching role could be thought of as double mediator. This idea of double mediator aligns with the shared learning commitments model where a teacher not only provides an intentional experience which can include the setup, materials and resources, but also selects potentially meaningful information from the experience and works with the children to make connections and form new understandings.

The SLC model draws on the notion of SST "where two or more individuals work together in an intellectual way to solve a problem, clarify a concept, evaluate activities or extend a narrative." (Siraj-Blatchford et al., 2002, p. 17). SST can be viewed as a sustained interaction between teacher and child where the teacher is attempting to enable the child to make sense of a problem, concept, activity or narrative. In this regard, the teacher's role would be as mediating artefact. As SST provided a basis for the SLC model, I argue that the construct of mediation is also a valid perspective from which to view and theorise the SLC model as I explain when addressing the findings later in this chapter.

Up to this point, I have defined the theoretical construct of mediation for this research and outlined how it provides insight and understanding into the findings that addressed the three research questions. I explain this in more detail later in this chapter, but first provide a rationale for mediation to be a valid theoretical construct for this research.

A rationale for mediation

Mediation can be viewed as a common thread which draws together STEM, working theory development and teaching approaches in this research. It provides a way to understand and theorise first why teachers might or might not become involved in STEM related teaching and learning experiences; second, how children might develop working theories; and third the teaching approaches used to foster and enrich STEM related working theories.

The notion of mediation aligns with teaching and learning in ECE. Internationally, mediation has been identified as an underpinning theoretical construct that is relevant to enriching children's thinking and concept development (Fleer, 2010; Gillespie & Zittoun, 2010;

Hedegaard, 2007). In a New Zealand study, Meade and Cubey (2008) also identified that mediation underpinned teaching approaches that extended children's thinking and understanding. Furthermore, the place of mediation in children's working theory development has been noted by Hedges (2012) and in my earlier work (Lovatt, 2013, 2014). Therefore, mediation holds a valid place in ECE, and in the teaching and development of working theories.

In *Te Whāriki*, mediation can be seen as an underpinning theoretical construct for teaching and learning. Sociocultural theorising is drawn on as one of the foundations of the early childhood curriculum document. Viewed through a sociocultural perspective, the notion of mediation can be inferred in the document which states that teachers "need to understand the importance, for young children's learning, of materials, artefacts and tools and the signs and symbols of societies and cultures." (MOE, 2017, p. 61). The theoretical construct of mediation can also be seen in the description of working theories, which are described as a means to make sense of the world. Mediation is therefore an aspect of the overall framework of *Te Whāriki*, and within the learning outcome of working theories.

STEM teaching and learning can be viewed through a mediating lens. Teachers can observe and recognise children's STEM related interests then use teaching approaches to mediate the children's learning (Tippett & Milford, 2017). Furthermore, as I argue later in this chapter, teacher perceptions and past experiences of STEM mediate teacher involvement in STEM related experiences.

The construct of mediation can be used to theorise teaching approaches that foster and enrich children's working theories. A link between mediation and teaching approaches that challenge and develop working theories has been made by Hedges (2012). She noted that teachers can challenge working theories through sensitive mediation. Hedges and Cullen (2012) also identified that children's working theories can be used by teachers to mediate and extend children's understanding. In my earlier research, I also linked mediation with teaching approaches that challenge children's working theories when investigating teaching approaches that invoke disequilibrium (Lovatt, 2014). Therefore, mediation has been identified as an aspect of teaching and learning in regards to working theories.

This thesis adds to the growing literature base about the notion of working theories, by theorising the links between mediation and working theory development. I draw and build on the previous working theory research and focus on the construct of mediation. Using mediation

adds depth and understanding to the spiral of working theory development model and the SLC model, and provides a lens to address the overarching research question.

I argue that mediation is a valid theoretical construct to draw upon for this research. The construct is accepted internationally and within the New Zealand ECE contexts. Mediation provides one way to theorise working theory development and associated teaching approaches. Mediation therefore adds depth to the understanding of the spiral of working theory development and SLC models introduced in chapters 4 and 5. The next section addresses the three research questions by adding the construct of mediation to the findings from chapters 3, 4, and 5.

Explaining the findings

In this section, I explain the findings of the research by applying a mediational lens. I move through the findings by addressing research questions 1 to 3 consecutively.

Addressing research question 1

In this section, I use the theoretical construct of mediation to explain the findings that address research question 1: How do teachers perceive the place of STEM education within ECE? I first explain the relation between concept, perception and mediating agent. Next, I relate the findings to literature about teachers' perceptions and argue that teacher perceptions are multi-faceted, dynamic and dependant on everyday circumstances. Using the mediational triangle, I then illustrate the interactions between teachers, the effect of their perceptions towards STEM, and their involvement in STEM experiences. Finally, I synthesise these explanations and illustrations to argue that teachers' perceptions mediate their STEM engagement.

Earlier in this chapter, I explained that concepts can act as mediating artefacts. I explained that concepts and perceptions are linked. I then argued that perceptions can also mediate involvement in exploring further that which a person holds perceptions about. For instance, if a person holds positive perceptions of gardening, it is more likely that they will do gardening than if they hold negative perceptions towards it. In this light, the main argument pertaining to RQ1is that that teachers' perceptions towards STEM education mediate their involvement in STEM related teaching and learning opportunities. Therefore, teachers' perceptions of STEM education in ECE can be considered mediating artefacts.

Teacher beliefs about children's early development might influence the time and attention that teachers give to STEM related experiences (Kinzie et al., 2015). Teachers' involvement in teaching and learning about STEM might also be influenced by their level of background knowledge as compared to their knowledge of other areas of learning such as language and literacy (Zucker et al., 2016). Lippard et al. (2019) found that there are many opportunities to capitalise on everyday STEM related learning experiences which are not taken up due to competing academic skills, and a limited background preparation in mathematics and science. I argue that beliefs, background knowledge and a demand to focus on children's academic skills all influence teachers' perceptions of STEM. These aspects align with the findings as I now describe.

In chapter 3, I identified that teachers could relate positive early experiences of STEM, and that there were more instances shared about science and mathematics teaching and learning experiences than technology and engineering. These findings are consistent with the perspective that perceptions mediate involvement. Early, positive experiences of mathematics and science may have provided a positive perception and therefore acted as a positive mediating artefact, leading to later involvement in science and mathematics related teaching and learning opportunities.

The findings also indicate that teachers operated in the continual flux where there are multiple learning areas such as literacy, a focus on dispositions such as creativity and a preponderance to build curriculum around children's interests. Having multiple learning areas in ECE is related to further findings that teachers could identify STEM learning in retrospect, but not always in the moment of the learning because the focus was not on STEM at that moment. From a mediational perspective, I argue that the priorities given to children's interests, literacy, and dispositions were affected by the teachers' perspectives of STEM education. In effect, this meant that STEM education was perceived as lower priority on many, but not all occasions. Other learning areas were then a dynamic influence on teachers' involvement of STEM education in ECE.

I also identified that teachers perceived STEM as being everywhere, throughout their centres, woven throughout *Te Whāriki*, but needing to be made visible. This perception could act as a positive or negative mediating artefact on teachers' involvement in STEM teaching and learning experiences. It might mean that teachers do not perceive a need to become involved in STEM learning, or alternatively it might mean that teachers perceive many opportunities

available which they can become involved in. Again, this perception is a dynamic influence on teachers' involvement in STEM education.

Surprisingly for me, the teachers perceived that subject knowledge was not an issue regarding teaching and learning about STEM. I expected that subject knowledge would be a barrier for teachers' involvement. However, teachers perceived that they could draw on each other's knowledge about STEM, and use ICT—with children, and also without children—to learn about STEM. The teachers' positive perception might have been related to the finding that STEM was perceived as being a process and outcome. As I outlined in chapter 1, teaching and learning in ECE focuses on both process and outcome, supported by the explanation of learning provided in *Te Whāriki*. Thus, teachers used ICT and drew on each other's knowledge to learn about STEM alongside children, learning about the skills of finding information—process—and simultaneously gaining information—content. In this regard, the positive perceptions towards STEM subject knowledge, coupled with the perception of STEM as process and outcome form a positive mediating artefact towards teacher involvement in STEM related teaching and learning opportunities.

All of these aspects that were identified in the findings can be considered to combine together, some acting positively, and some acting negatively, to create a dynamic teacher perspective of STEM related teaching and learning. From a mediational perspective, the combination of these aspects form dynamic perspectives which mediate the teachers' engagement in STEM related teaching and learning experiences. I have illustrated this in Figure 15 below.

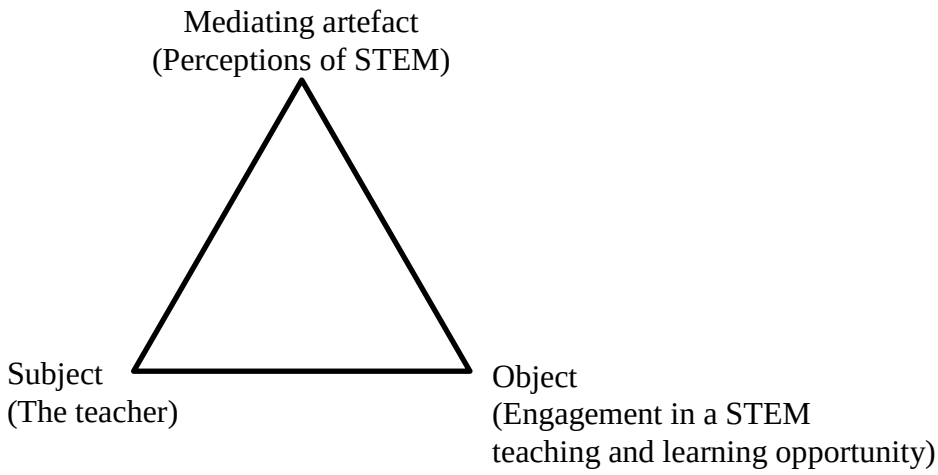


Figure 15. The mediational triangle and teachers' perceptions toward STEM.

Figure 15 illustrates that teachers' perceptions of STEM mediate their engagement in STEM related teaching and learning opportunities. If the perception is positive, then the teacher is more likely to engage in the opportunity than if they hold negative perceptions. As noted earlier, perceptions are dynamic, therefore teacher perceptions are likely different over the day and over different days.

Up to this point, I have argued that teacher perceptions act as mediating artefacts on teachers' involvement in STEM related teaching and learning opportunities. Mediation is therefore an underpinning theoretical construct that provides insight into teachers' perceptions. I now move my attention to the development of children's working theories about the STEM domains, using mediation to explain and theorise the findings related to research question 2.

Addressing research question 2

This section uses a mediational perspective to conceptualise theoretically the findings that addressed research question 2: How might young children develop working theories related to the STEM domains? I argue that working theories can be considered as dynamic mediating artefacts of further working theories. This argument aligns with Cole's (1996) and Vygotsky's (1998) reasoning that mediating artefacts can be purely conceptual. I argue that working theories can then be considered as mediating artefacts both in their three-fold nature as process, outcome, and interpretive framework and as in the overall working theory. All three aspects can be viewed as mediating artefacts as I illustrate further in this section.

The notion that working theories mediate further working theory development builds on Vygotsky's (1998) proposition that concepts can act as mediating artefacts. He argued first,

that concepts provide a complex mental system in which an object is situated; and second, that connections and relations between the object and the subject are mediated by those concepts. This view was related to working theories by Hedges (2012) who stated that working theories might “be viewed as acting as implicit mediators within children's active attempts in their own minds to extend and challenge their thinking” (p. 146). This statement is significant for my research, as it relates the three-fold view of working theories described in chapter 4 (Figure 7) to the mediational triangle.

Each of the three aspects of working theories—process, outcome, and interpretive framework—can be considered as mediating artefacts. First, the processes used to form and enrich working theories are mediating artefacts as they enable the child to make sense of the new information. Second, a working theory can act as an interpretive framework through which new information is passed, sense is made, and connections formed. Third, as Wartofsky (1979) noted, “our own perceptual and cognitive understanding of the world is in large part shaped and changed by the representational artefacts we ourselves create” (p. xxiii). By substituting the outcome aspect of working theories for Wartofsky’s perceptual and cognitive understanding, then the outcome aspect also can act as mediating artefacts. Therefore, working theories can act as mediating artefacts. Since working theories can act as mediating artefacts, the three-fold view of working theories can be overlayed onto the mediational triangle as per Figure 16.

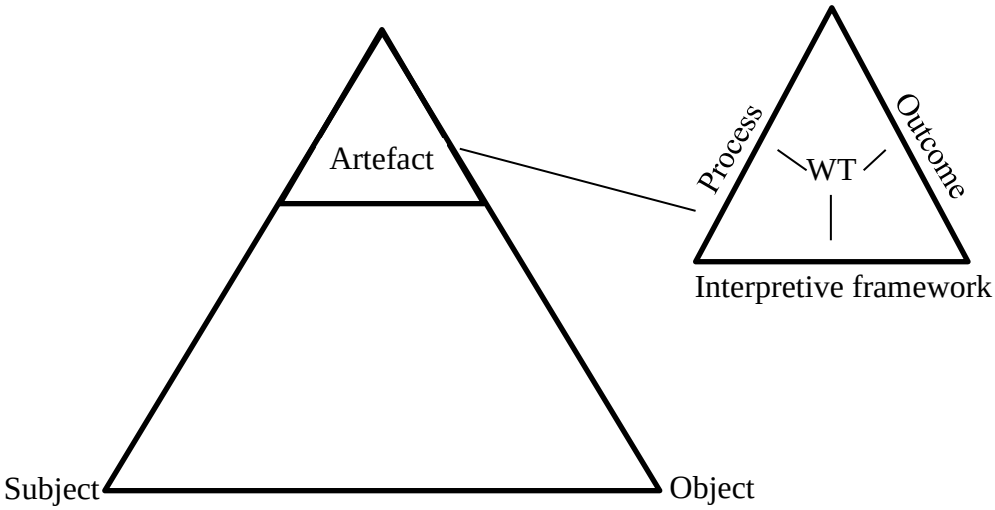


Figure 16. A three-fold view of working theories overlayed onto the mediational triangle.

To explain how this view relates to the findings, I exemplify in relation to the climbing frame vignette from chapter 4. In that vignette, Poppy was the subject, attempting to reach the overhead bars of the climbing frame by jumping onto and off a foam wedge. I suggest that amongst many other things, the object can then be considered conceptual. That is, Poppy was trying to make sense of where on the wedge she should land and jump from—she was developing working theories about the function of the wedge in relation to her use of it. The mediational triangle can then be viewed as Figure 17 depicts:

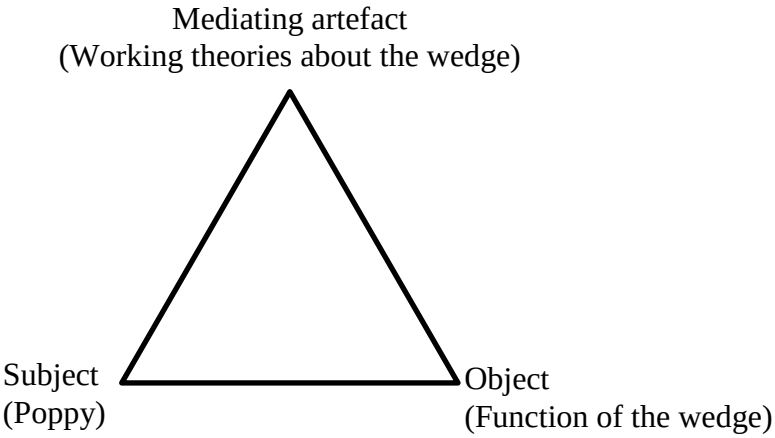


Figure 17. The mediational triangle and Poppy.

The tentative and evolving nature of working theories means that they not only act as mediating artefacts, but simultaneously are mediated. Therefore, in this example, Poppy's current working theories about how the wedge functioned mediated her ongoing use of the wedge. At the same time, her ongoing experiences of using the wedge mediated her working theories.

Therefore, when acting as mediating artefacts, working theories continue to evolve, and can then be considered as dynamic artefacts. This view of the dynamic nature of the mediating artefact aligns with Wells' (1999) views. He found that as the learner is transformed, the way they perceive, interpret and represent the world changes. The mediating artefact is reconstructed based on these new perceptions, interpretations and representations. Therefore, the artefact is transformed. Wells went one step further than this research, positing that the transformed mediating artefact affects other members of the culture, resulting in new understandings and practices not only by the individual, but by other members. It is very likely that Poppy's dynamic mediating artefact also resulted in new understandings and actions by the other children involved in the jumping experience, however that has not been the focus of this research.

In chapter 4, in the jumping vignette, I proposed a three-fold view of Poppy's working theories. Overlaying the three-fold view of working theories onto the mediational triangle results in the following:

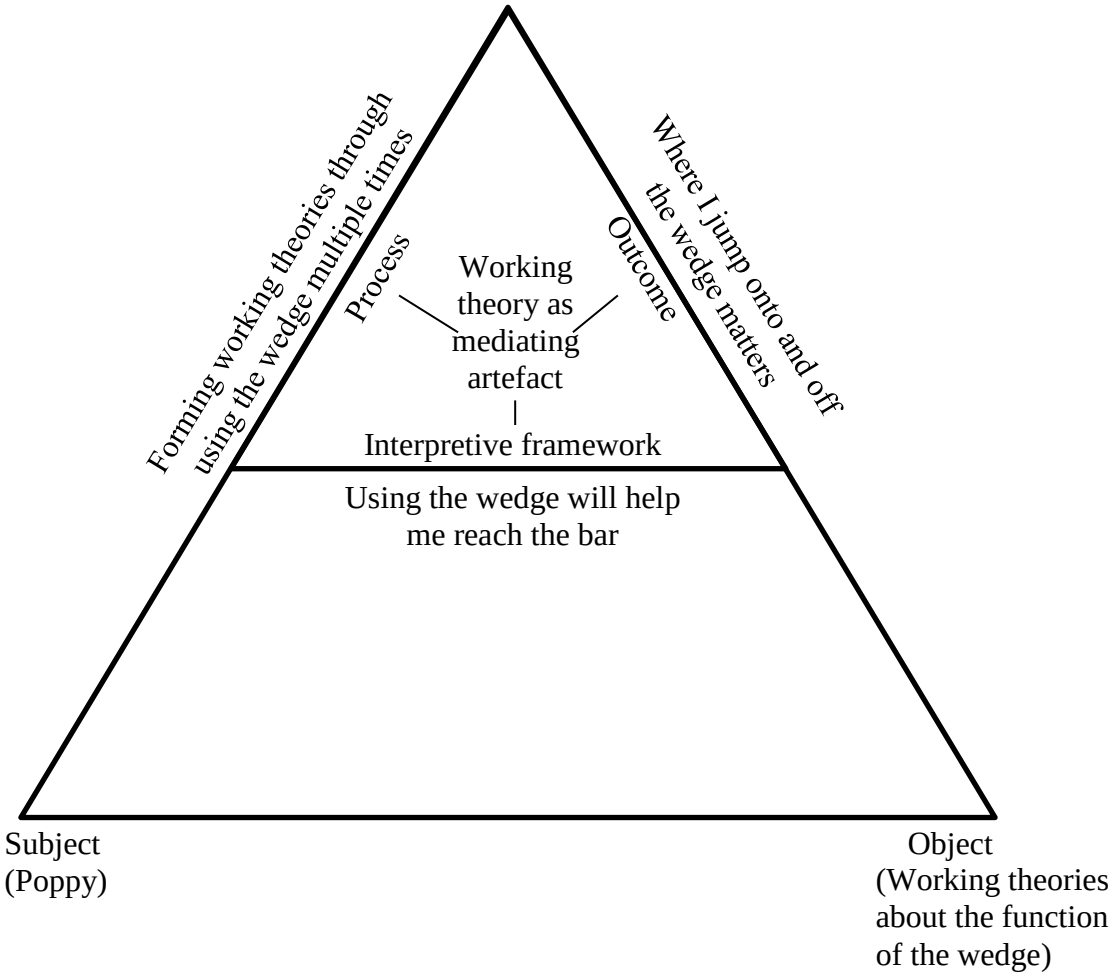


Figure 18. Poppy's working theories and the mediational triangle.

Figure 18 illustrates that the working theories which Poppy was developing about the function of the wedge mediated her use of the wedge, and mediated her understanding of how the wedge functioned. As she experimented by using the wedge, Poppy's working theories about the wedge were modified. Her interpretive framework acted as a mediator by underpinning her understanding that the wedge was useful. The process of forming the working theories through experimentation mediated her understandings, and the understandings formed mediated the modification of further working theories as she experimented further. The understandings enriched Poppy's interpretive framework which mediated the new information she gained from subsequent experiences. Poppy's working theories therefore acted as mediating artefacts.

As I argued in chapter 4, the process of developing a working theory is an iterative, recursive process. Furthermore, as I noted above, as a working theory mediates, it too can be (and perhaps always is) modified. This modified working theory might then re-mediate the existing understanding, or result in new information being sought, and working theories further modified. Therefore, I return to the spiral of working theory development to explain this process.

Mediation forms a theoretical underpinning to the spiral of working theory development model. While Wells (1999) focused on the notions of knowledge building and knowledge construction which could be considered constructivist, links between the spiral of knowing and mediation can also be seen in his writing, for instance:

> it is our understanding that constitutes the interpretive framework in terms of which we make sense of new experiences and which guides effective and responsible action. Thus, although first-hand experience provides an essential basis for understanding, it needs to be extended and reinterpreted through collaborative knowing, using the informational resources and representational tools of the wider culture. (Wells, 1999, p. 85)

Wells' use of the terms 'make sense', 'interpretive framework', and 'reinterpreted' indicate that from a mediational viewpoint, the spiral of knowing hinges on the element of understanding. It is the existing understandings that form the basis for which new information is made sense of. As explained in chapter 4, the spiral of working theory development model builds on the spiral of knowing. Considering the mediational nature of the spiral of knowing, next I also theorise the spiral of working theory development through a mediational lens.

Because a working theory can act as a mediator, then each of the four elements of the spiral of working theory development model must have a mediational aspect. The first element—understanding—is tentative and evolving because working theories are tentative and evolving. The understanding acts as an artefact, mediating new information in that by being tentative it allows new understandings to develop as new information is experienced and incorporated. The second element—experience—in itself can be considered a mediating artefact, just as resources and materials are. However, for this research, while acknowledging that experiences can mediate learning, it is the third element—the information gained from the experiences—that is the critical aspect of being a mediating artefact. Nevertheless, the experience provides more than just information, it is also the feelings, emotions and senses that contribute to mediating learning. The fourth element—making connections—is the crux of mediation in

regards to the spiral of working theories. This element is where connections are made between existing understandings and the new information, and where existing understandings mediate the new information. At the same time, as I have already noted, it can be argued that the new information mediates the existing understandings. Therefore, the making connections element is a complex mediating space where understandings function as dynamic mediating artefacts, and new information functions as mediating artefacts, both mediating each other.

To illustrate how mediation applies to the spiral of working theory development model, I now turn to the castle construction vignette from the findings section in chapter 4. To recap, in this vignette, Jack applied sticky-tape to two rulers which were standing vertically beside his construction. Rather than place the tape across the connection between rulers and blocks, he only placed it on the ruler, not connecting it to the structure. However, by chance the ruler balanced. Rebecca, another child was surprised at first, but then copied Jack's application of sticky-tape. To conceptualise the mediating nature of the spiral of working theory development model in regards to the castle construction, I return to the two iterations of the spiral from chapter 4.

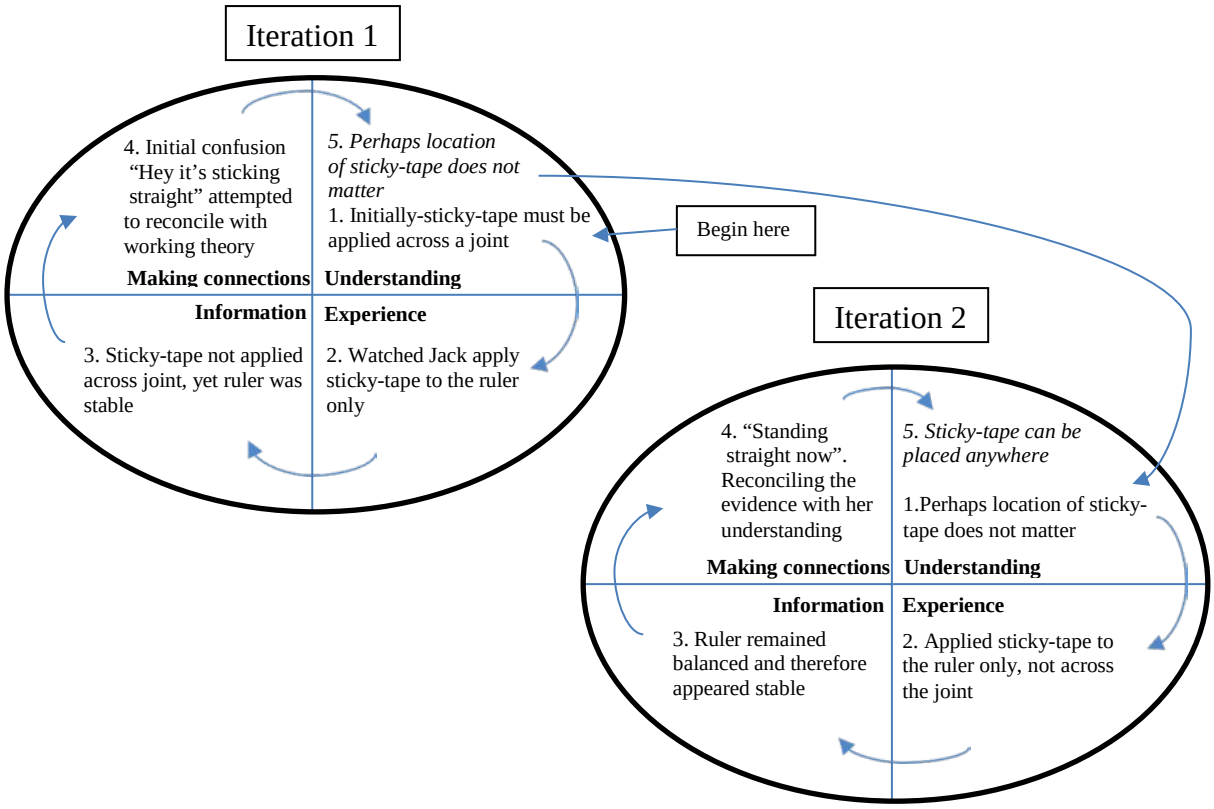


Figure 19. Rebecca's understandings.

In iteration one, Rebecca's existing working theory that sticky-tape must be applied across a joint served as a conceptual artefact for what followed. As noted earlier, while the experience of watching the tape being applied could be said to be a mediating artefact, the information Rebecca gained from the experience is my focus. Rebecca's understanding that sticky-tape must be placed across the joint mediated the information gained, evidenced by her saying "hey it's sticking straight" in a confused tone. However, the new information also mediated her existing understanding, resulting in a new understanding: that the location of the tape did not matter. The second iteration reinforced her new understanding that the location of the tape did not matter. Rebecca then went on to place the sticky-tape in places other than across the joint.

While Rebecca's working theories about the use of sticky-tape became less conceptually accurate, I propose that through mediation her working theories became enriched. Rebecca might have formed new working theories about the properties of sticky-tape. Indeed, at times I have re-watched this episode wondering if my own working theory that the tape must be placed across the joint might have been inaccurate, and that something else might have been happening. Although further data did not include examples of Rebecca's continuing developing working theories about sticky-tape, I suggest that through another later experience, and through further experimentation, she might modify her working theory to include that the location of

the tape is crucial. Perhaps the new working theory will prompt reflection on the experience which I recorded, leading to further enrichment of her working theory about sticky-tape, or even further into working theories about balance and centre of gravity. However, this is pure speculation and could be the focus of further research that follows the development of working theories over time.

The purpose of this section has been to theorise the findings to reach a point where I can address the second research question: How might young children develop working theories related to the STEM domains? In short, I propose that one way that children develop working theories about the STEM domains is by using their existing working theories as mediating artefacts.

As I have already argued, working theories can act as interpretational filters, or conceptual tools. Being a combination of knowledge, skills and attitudes, working theories provide a three-fold combination of mediation: First as knowledge, or as conceptual artefacts, they mediate new understandings as children make sense of new information in light of already held understandings. Second, as skills, they are a conceptual artefact that consists of skills needed to make sense of new information. Third, as attitudes, working theories contribute to curiosity, confidence, motivation, courage, open-mindedness, and willingness to investigate, to undertake new experiences, to see new information, and to attempt to make sense of it. Together then, and simultaneously, working theories function as mediating artefacts that provide knowledge to relate new experiences to, skills to undertake the relating, and attitudes to motivate children to do so. In this sense, working theories can be considered mediators through which understanding is made of new information and experiences.

The spiral of working theory development model in chapter 4 can then be viewed as a dynamic model of mediation where each element can act as a mediating agent, resulting in enriched working theories. The model illustrates how working theories can be mediated, so can be considered a mediating artefact in itself. At the same time, the model becomes mediated as each element can be mediated by the new understandings, experiences, information and connections made. Therefore, the model itself acts as mediator, and is mediated.

Therefore, to address research question 2, the spiral of working theory development can be viewed as a model that shows how working theories are mediated, resulting in enriched working theories. Each of the four elements of the spiral model can be viewed as mediators. At the centre of the spiral, and incorporating all four elements of the spiral is working theories itself, which can also be viewed as a mediator. In other words, existing working theories

mediate the development of new working theories. As part of that process, new working theories might be formed, and the existing working theories that acted as mediators might be enriched.

I now move to research question 3. In the following section, I explain and theorise the findings related to teaching approaches through the lens of mediation.

Addressing research question 3

This section continues the mediation theme by addressing the findings of research question 3—how might teachers foster and enrich children's working theories about the STEM domains—through a mediational lens. First, I introduce the idea that teaching approaches can be considered as mediating artefacts of children's learning. Next, I explain two perspectives on mediation in terms of teaching approaches by taking a broader teaching and learning perspective, and a teaching perspective. I then theorise and explain the SLC elements using the lens of mediation before addressing research question 3 through a mediating perspective.

The idea that mediation underpins teaching approaches is not new (Daniels, 2015; Fleer, 2009a; Wertsch, 2007). Mediation has been identified as underpinning teaching approaches that mediate children's working theory building (Hargraves, 2013; Hedges, 2008, 2012; Lovatt, 2014; Lovatt & Hedges, 2015) and STEM learning (Carr, 2001; Fleer, 2009; Moomaw, 2013). My study adds to this prior research by highlighting the place of mediation in regards to a teaching model—the SLC model. I show the importance of a mediational lens to theoretically inform the understanding of how the SLC model works, adding greater depth to the understandings about how teachers might foster and enrich children's STEM related working theories.

Importantly, as mentioned previously, mediation is not a specific teaching approach. Instead it provides a theoretical foundation that underpins teaching approaches. Effectively, the SLC model is then based on the foundation of mediation. This is one theoretical perspective of the model. Further aspects of mediation such as scaffolding (Berk & Winsler, 1995) and the zone of proximal development (ZPD) (Vygotsky, 1978) could also be explored. I embrace the idea that these mediational aspects might provide a highly illustrative theoretical underpinning of the SLC model. However, because the model is new, I feel that a broader mediational perspective should be taken. Further research could be undertaken which applies perspectives such as scaffolding and the ZPD or alternative theoretical constructs.

A key concept of this section is the relation between teachers and mediation. If we return to the mediating triangle discussed earlier, and if mediation can be thought of as human and symbolic (Kozulin, 2003), then teachers' approaches can be thought of as mediating artefacts of children's understandings and learning. This means that teachers can then be considered as mediating artefacts in children's learning, using and providing signs and psychological tools. It is important to be clear that in themselves, as a static physical being, teachers do not mediate concepts. Although a teacher's presence might be considered a mediating agent because they might attract children to an activity or experience (Kozulin, 2003), this is not the focus of my research. Instead, I am focusing on the involvement in teaching and learning that teachers make, and therefore the approaches they use that mediate children's working theories.

The mediational triangle can be used to theorise the SLC model from multiple perspectives. For my research, I have used two perspectives. First, from a broader teaching and learning perspective where the subject is the children, the object is the children's working theory, and the artefact is the teaching approach(es) (see Figure 20-1). With a small change, a second perspective of the relationship between mediation and the SLC can then be gained. I call this the teacher's perspective. Using this perspective, what was the artefact (teaching approach) in the learning and teaching perspective now becomes the object. The subject is now the teacher, and the new mediating artefact is the teacher's understanding of the child and the concept (see Figure 20-2). In short, by understanding the child, the concept, and the child's understanding of the concept, the teacher can then use teaching approaches to foster and enrich the child's working theories about the concept. Both perspectives are illustrated in Figure 20.

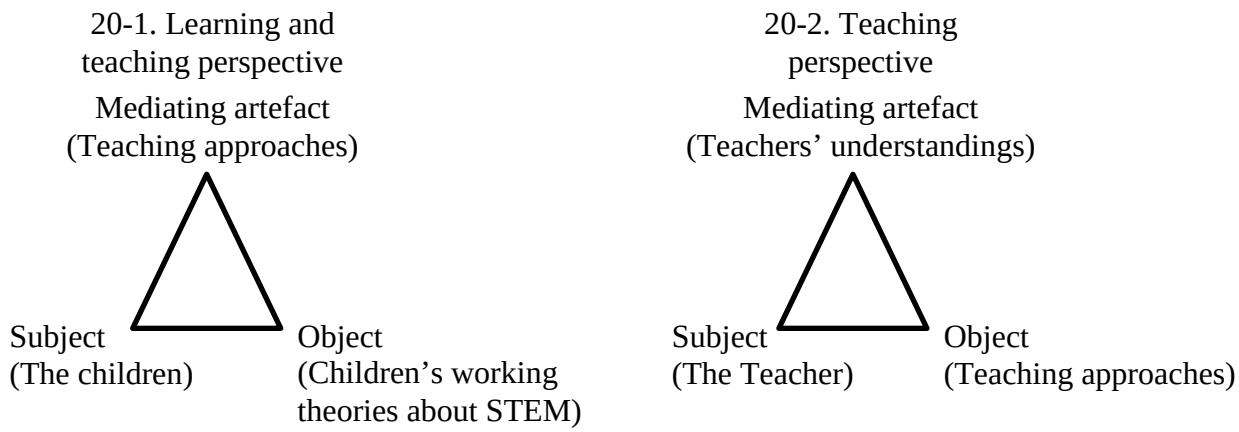


Figure 20. Two perspectives on the relationship between mediation and the SLC.

In short, Figure 20-1 shows that teaching approaches mediate children's working theories about the STEM domains. By shifting the focus onto the teaching approaches, the mediational triangle then becomes as per Figure 20-2. In this configuration, the teaching approaches used are mediated by the teacher's understanding of the child, the concept, and the children's understanding of the concept. The central element of the SLC model is therefore called understanding. This element is the foundation on which the three outer elements are based. The second perspective (the teaching perspective) has been used to theorise the elements of the SLC model. This is the focus of the next section, where I begin with the element of providing intentional experiences, followed by making selected information available, and end with making connections.

Intentional experiences

The first outer element of the SLC model—providing intentional experiences—relies on teachers understanding children. Because the focus of this element is on providing experiences that are potentially meaningful to the children, then an understanding of the children must be required. In addition, some understanding—even if limited—of the concept that the child is developing working theories about must also be required. Furthermore, by understanding the child's understanding of the concept, the teacher might then have an informed understanding about introducing a new experience, or modifying the existing experience to challenge, refine, or broaden the child's working theory. The understandings then function as a mediating artefact for the teacher. Without these understandings, the experiences provided might be haphazard, and potentially not meaningful at all.

Figure 21 below illustrates the conceptualisation of mediation and meaningful experiences. In this case, the mediational triangle involves the teacher as subject, potentially meaningful responses as the object, and understanding of the child, the concept, and the child's understanding of the concept as the mediating artefact.

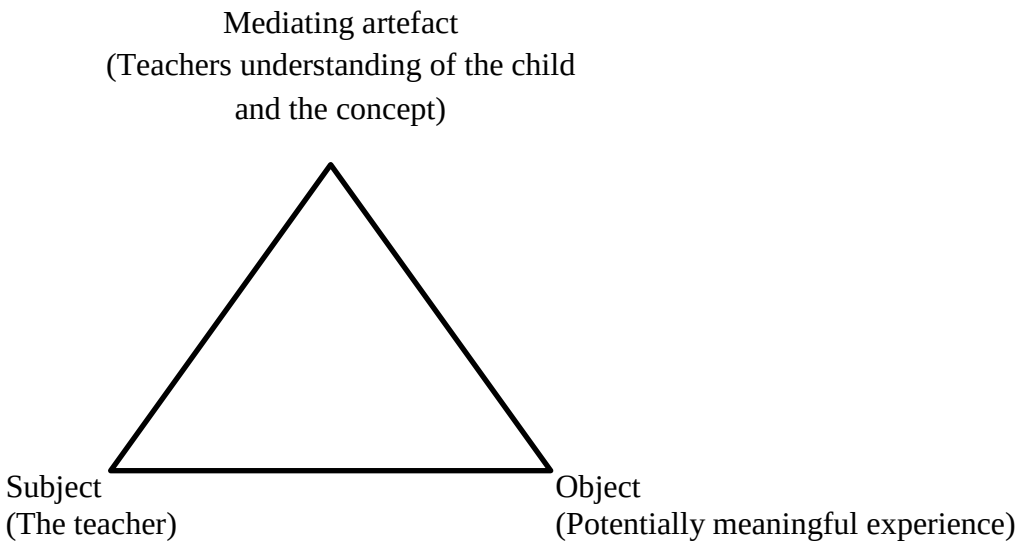


Figure 21. Mediation and providing intentional experiences.

The experience from chapter 5, where the children and teacher were disputing the shape of stars illustrates this element. To recap, following a visit to the observatory, a teacher talked about the shape of stars being circular, not star-shaped. She then found information using a computer tablet and shared the information with the children who were resistant to acknowledging that stars are circular. Importantly, this was not a fleeting interest, the interest in stars had been ongoing for a while, likely resulting in the teacher understanding the children's understanding. The teacher had also been sitting with the children while they made stars from playdough, listening and observing. She had noted that teaching was about listening and observing, to plan an appropriate response. In this case, her response was based on her knowledge that stars are circular, and that the children believed stars were star-shaped. Her response was also based on her understanding of the children: she knew the children had been to an observatory where they had been shown that stars were circular, yet they still held deep seated beliefs that stars were star-shaped. She challenged a likely source of this deep belief: the song twinkle, twinkle, little star. From a mediational triangle view, the subject was then the children, the object was the working theories about the shape of stars, and the mediating artefact was the experience of engaging with the children in the discussion about the shapes.

Therefore, a teacher's understanding functions as a mediating artefact in terms of providing intentional experiences. The understandings mediate the teacher's approach to the children's interests, enabling the teacher to provide an experience which builds on their understandings, and potentially provides a learning experience of interest to the children, resulting in the children's engagement in learning. As I explained earlier, the experience provides a context for information to be gained. The teacher's role is then to make selected information visible as I explain next.

Selected information

The second outer element of the SLC model—making selected information visible—can also be viewed through a mediational lens. To recap, this element focuses on the teacher selecting potentially meaningful information from or during an experience and making it visible to the children. As Kozulin (2003) suggested, a teacher's role is to mediate the information available in an experience. In the case of the SLC, that role is to make selected information visible. The question can then be asked: How does the teacher know that the information that they select will be meaningful to the children? Like the first outer element (providing intentional experiences), understanding is again the key. And again, understanding is three-fold: understanding the children, the concept, and the children's understanding of the concept. Therefore, understanding again mediates the teaching approaches used. Just as with the first element, this three-fold understanding can lead to the teacher making information available that fosters, enriches, broadens and challenges the children's working theories.

In figure 22, I illustrate the function of mediation in terms of selecting potentially meaningful information. Here, the teacher is the subject, making potentially meaningful information visible is the object, and understanding is again the mediating artefact.

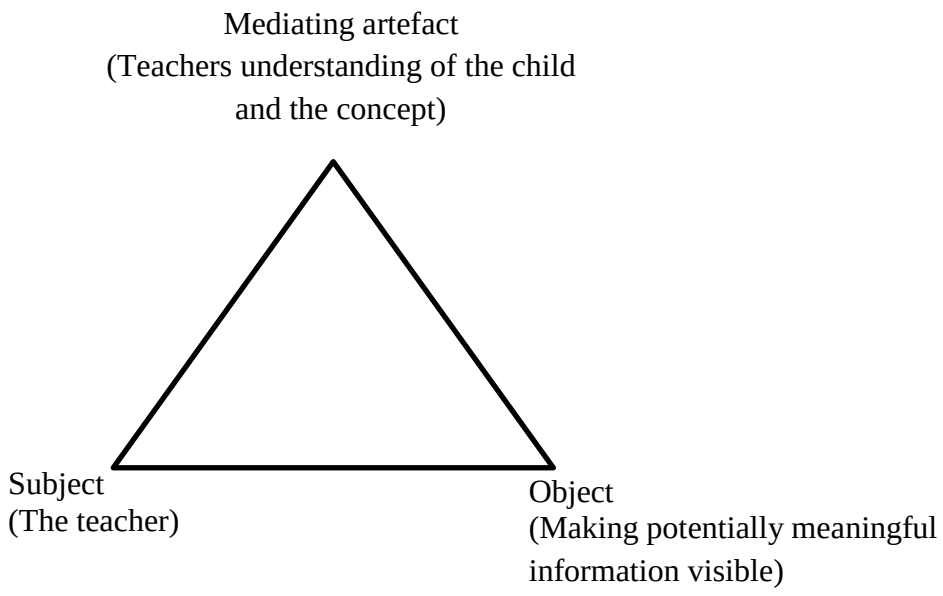


Figure 22. Mediation and making potentially meaningful information visible.

To provide clarity to Figure 22, I draw once more on the findings from chapter 5, this time a small part of a discussion between two boys and two teachers about transporting bicycles to a park using a vehicle. The boys had suggested that they could hold the bicycles beside them in the rear of the vehicle, and were challenged by the teachers about this method. The first teacher asked the children what would happen if the brakes were applied suddenly. As the children did not understand her question she asked again. The children still appeared confused. The other teacher re-stated the question and added a physical action that the children understood by clapping one hand forward into the other hand to indicate a sudden stop. It was this information that prompted the boys to re-think their method of transport.

A mediational perspective of the second element provides an understanding of this small excerpt. The first teacher understood the children's objective. Effectively, it was to form an acceptable working theory about how to transport the bicycles. She also understood the concept of stopping suddenly, so perhaps understood the physical effects of momentum, inertia and force. However, it appears that she did not understand the children's understanding of the concept sufficiently to challenge them in a way that they understood. However, the second teacher held understandings about the children's objective, the concept, and the children's understanding of the concept. She then asked the question while adding a gesture which together provided meaningful information to the children. One child repeated the same gesture after thinking about the teacher's challenge, indicating that the information provided was indeed meaningful.

Therefore, a teacher's understanding functions as a mediating artefact in terms of selecting potentially meaningful information to make visible to the children. Importantly, I make no claims to say that understanding will lead to meaningful information. Instead, I use the key word potentially. Understanding will lead to potentially meaningful information, but a claim cannot be made to say that it will necessarily be so. Children's learning is far too complex to be approached with certainty. However, I do propose that some understanding can lead to teachers providing information that is more meaningful than that provided with little understanding. What kind and how much understanding has not been the subject of this research, and is ripe for future studies.

Making connections

The third outer element of the SLC—making connections—can also be viewed through a mediational lens. Making connections focuses on the teaching approaches that potentially enable children to make sense of the new information in light of their already held understandings. This element is important as a guarantee cannot be made that children will relate new information to existing understandings even if the relationship appears obvious (Kozulin, 2003). Once again, understanding is the key and can be considered as the mediating artefact that leads to making connections. An understanding of the child, of the concept, and of the child's understanding of the concept is paramount to the teaching approaches used to work with children to make connections. For instance, an understanding of the child's prior experiences might enable the teacher to bring these up as concrete experiences that the child can draw on to relate new information to. An understanding of the concept might provide a basis for the teacher to raise a meaningful question, and an understanding of the child's understanding might provide the basis for the teacher to probe and explore that child's understanding, leading the child to make further connections. The function of making connections as a mediating artefact in teaching approaches is shown in Figure 23.

In Figure 23, the teacher is again the subject. This time the object is fostering connection making by the children to develop enriched working theories. The mediating artefact remains understanding. Again, understanding the child, the concept, and the child's understanding of the concept enables the teacher to use approaches that are meaningful to the child, and in this case that prompt connection making.

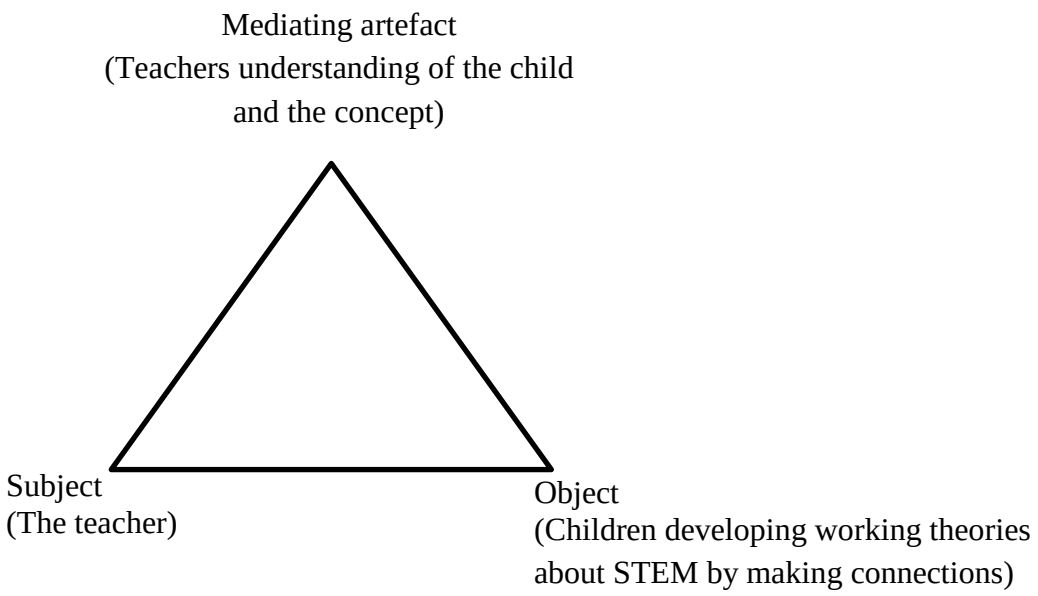


Figure 23. Mediation and making connections.

To illustrate Figure 23, I turn again to the findings and in this case, the episode about domino building from chapter 5. Over multiple experiences, the children had used wooden blocks placed on their ends and spaced apart to make a domino run. The teacher understood the children well, that they had an ongoing interest in building domino runs, and that they problem-solved well. She understood the physics of the domino run: that placement and alignment of the blocks was important, and she had watched the boys build multiple domino runs over time, and understood that they were gradually developing their working theories about the physics involved. The children were prompted to make connections when she asked a question and then voiced an observation, finishing with the words “that’s interesting”. And while the boys did not respond immediately it is likely that they silently made connections, as later in the day they were able to provide answers to the same challenges in their construction of further domino runs.

Therefore, a teacher’s understanding functions as a mediating artefact in terms of making connections. The understandings mediate the teacher’s approach to the children’s learning experience, enabling the teacher to prompt the children to make connections between existing understandings and new information.

Up to this point, I have developed an argument that mediation is a valid theoretical construct to explain and add depth to each element of the SLC model. I now draw these elements together to address research question 3.

Mediation and the SLC

To address research question 3—how might teachers foster and enrich children's working theories about the STEM domains—I began with two perspectives on the relationship between the SLC model and the mediational triangle. I have used the second perspective, which I call the teaching perspective to add a theoretical layer to each of the elements of the SLC. I now return to the first perspective, which I call the broader learning and teaching perspective and use both perspectives to address research question 3.

In short, teachers foster and enrich young children's working theories about the STEM domains through mediation. Viewed from the second perspective, teachers' understandings (of the child, the concept, and the child's understanding of the concept) mediate their teaching approaches. And from the first perspective, teaching approaches mediate the enrichment of children's working theories. Figure 24 below illustrates this relationship.

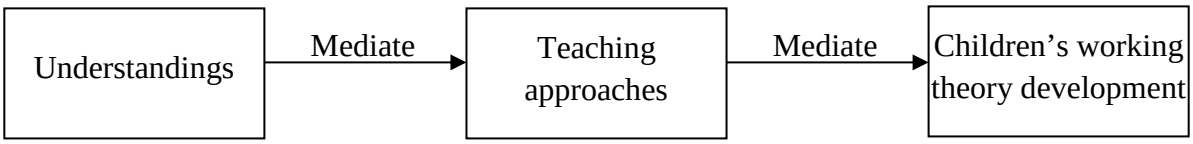


Figure 24. Mediation of children's working theories.

Because this research focuses on the SLC as a teaching approach, and because understanding is the central element of the SLC, then the understanding and teaching approaches elements of Figure 24 can be combined into one element as per Figure 25 below.

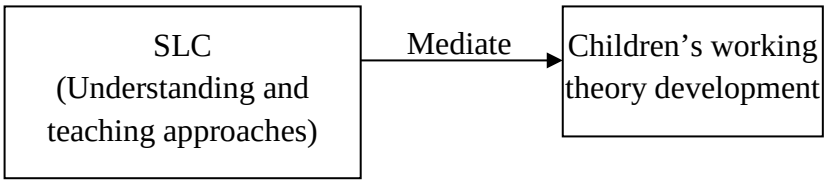


Figure 25. Combining the understanding and teaching approaches aspects.

Therefore, the SLC model can be viewed as a mediating artefact of children's working theories as per Figure 26 below.

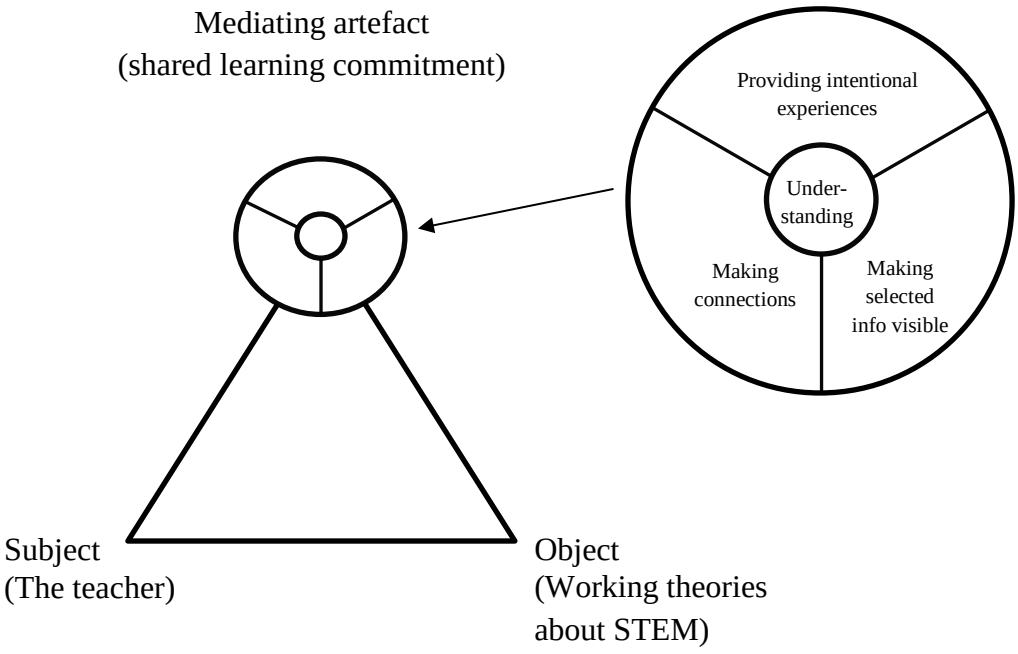


Figure 26. The SLC as a mediating artefact.

I now return to the castle construction vignette from chapter 5 to illustrate how this model works. From the first perspective, the children were developing working theories about the placement of sticky-tape and the stability of the ruler. The teacher was the mediating artefact, mediating the children's working theories. From the second perspective, the teacher was using and developing teaching approaches to foster and enrich the children's working theories. The teaching approaches were mediated by the teacher's understanding about how these two children learn through guided experience, that they were interested in the concept of supporting the rulers to stand upright, and that they understood that sticky-tape was needed in some way to support the rulers. The teacher understood the concept—that tape must be applied across the joint—and she worked with the children, suggesting they add tape across the joint. However, the teacher became distracted by other children, just as the ruler stood up inadvertently after the tape had been applied in the wrong place. She therefore did not understand Jack's or Rebecca's developing and conceptually incorrect understanding of the concept. The children enriched their working theories about sticky-tape and stability, but not in a conceptually accurate way.

Therefore, mediation underpins the SLC model, providing depth and understanding to each element and to the model overall. In each element, teachers' understandings of the child, the concept, and the child's understanding of the concept mediate the teaching approaches used. The teaching approaches then mediate children's working theory development. Therefore, to answer research question 3, teachers foster and enrich children's working theories about the STEM domains through mediation. That is, teachers act as mediating artefacts that foster working theory development. Of particular importance to their mediating role, is understanding. Understanding leads to potentially meaningful responses in the form of experiences, the information teachers select to make visible in those experiences, and the connections that the teachers and children make,

Up to this point, I have developed an argument that mediation is a key theoretical construct that can be used to explain and theorise the findings for each supporting research question. In the next section, I build on my argument to address the overarching research question for this study.

Addressing the overall research question

In the previous sections, I have addressed the three supporting research questions from a mediational viewpoint. I now draw on those sections, and particularly the sections addressing research questions 2 and 3 to address the overarching question which is how might STEM related working theories be developed, fostered and enriched in early childhood education settings?

How might STEM related working theories be developed, fostered and enriched in early childhood education settings? Through mediation. This theoretical construct provides a lens to understand and theorise how STEM related working theories were developed by the participants in this research. Mediation adds depth to the understanding of the spiral of working theory development model which represents how children developed working theories in this research. It also adds depth to the SLC model which describes how teachers in this research fostered and enriched children's working theories. I explain this in more detail next.

Mediation provides a way to explain and theorise both models developed through this research. First, each element of the spiral of working theory development model can be viewed as a mediating artefact. So too can working theories in themselves. Existing working theories can act as conceptual mediating artefacts in the development of new working theories.

Simultaneously, those existing working theories that were mediating artefacts might be enriched too. Therefore, working theories can be viewed as dynamic mediating artefacts. Second, the SLC model in itself, and each element of the SLC model can be viewed as a mediating artefact. Third, teachers can be considered as mediating artefacts of children's learning. Therefore, teaching approaches mediate learning. In regards to this research then, the SLC model illustrates one way teachers can mediate working theory development. The notion of understanding, that is understanding the child, the concept, and the child's understanding of the concept is central to the SLC model. Therefore, understanding mediates the SLC, and hence mediates working theory development.

Summary

The focus of this chapter has been on the mediating artefacts that underpin the development of working theories and the associated teaching approaches. Mediation provides a lens to theorise how children develop working theories and how teachers foster and enrich children's working theories. In short, mediation involves the use of mediating artefacts—processes and tools—to make meaning within a cultural system. Mediation is not a teaching technique; it is a theoretical construct that provides a foundation and lens for teaching approaches to be built upon. Mediation then provides theoretical depth to the findings and therefore, understandings of working theory development and associated teaching approaches.

In this chapter, I have argued that mediation is one way to theorise the supporting research questions, beginning with teachers' perceptions of STEM which I propose act as mediating artefacts in regards to teacher engagement in teaching and learning opportunities. I have then used mediation as a theoretical perspective to view the spiral of working theory development model, arguing that existing working theories mediate new working theories. I have also used mediation as a theoretical lens to view the SLC model, arguing that mediation underpins each element of the model, and that the SLC model itself can be viewed as a mediating artefact of children's working theories. I have addressed the overarching research question in two parts: First, by arguing that the SLC model explains one way that teachers foster and enrich children's working theories when it is viewed through a mediational lens. Second, by arguing that the spiral of working theory development model can also be viewed through a mediational lens to explain how children develop working theories about the STEM domains. I expand on the way that mediation addresses each of these research questions next.

Teachers' perceptions of STEM act as mediating agents in relation to teachers' engagement in STEM related teaching and learning opportunities. Teachers' ideas about, beliefs of, and images of STEM education in relation to ECE constrain or afford the likelihood of teachers becoming involved in STEM related experiences with their children.

The spiral of working theory development model shows one way that children develop working theories about the STEM domains. When viewed through a mediational lens, I have argued that greater depth and understanding of the model is provided. Each element of the spiral can be viewed as a mediating artefact, and furthermore, working theories in themselves can then be seen as mediating artefacts of new working theories. In addition, existing working theories are likely mediated by the new information, understandings, and working theories developed. Therefore, existing working theories are dynamic mediating artefacts of new working theories.

Similarly, the SLC model represents one way that teachers can foster and enrich children's working theories about the STEM domains. Again, a mediational lens adds greater depth and understanding to the model. The central element—understanding the child, the concept, and the child's understanding of the concept—is key to the SLC and can be viewed as a mediating artefact for the teaching approaches. In this way, understanding mediates teaching approaches, which mediate children's working theory development.

Therefore, I address the overarching research question—how might STEM related working theories be developed, fostered and enriched in early childhood education settings—as follows: teachers' perceptions of STEM education in early childhood settings mediate their involvement in STEM related teaching and learning opportunities. The teaching approaches used are mediated by teachers' understanding of the child, the concept and the child's understanding of the concept. The children's working theories are mediated both by the teaching approaches used, and the existing working theories that the children hold.

The two models: the spiral of working theory development, and the SLC, have provided dynamic frameworks to address the research questions. The models have evolved throughout the entire research and will likely continue to evolve through further research and theorising. Just as learning experiences are transformative in that they transform individual participants and their potential for future participation, the models are potentially transformative. They provide a new way to view working theory development and teaching approaches, and they provoke further research.

The next chapter is the conclusion to this thesis. In it, I briefly summarise each chapter, discuss the limitations, significance and contribution that this thesis makes to understandings, theorising and modelling the development of working theories and associated teaching approaches. I explain potential implications, and offer my thoughts on the directions of further research that could result from this study.

7. Conclusion

Kua hua te marama

The moon is full, the cycle is completed. (Mead & Grove, 2001)

This research set out to investigate young children's working theory development and teachers' roles in enriching and fostering that development. In doing so, I have created two original and innovative models that represent how children develop working theories, and how teachers can foster that development. I have theorised these models using the construct of mediation, providing a lens which explains the theoretical basis of the development of working theories and of the associated teaching practices. These models and the associated theorising offer an original and significant contribution to scholarly literature in the area of working theory development, and as argued earlier in this thesis, with the similar concepts of thinking, concept development, and knowledge building.

The key argument of this thesis revolves around mediation. First, that teachers' perceptions of STEM education in ECE mediate their involvement in potential STEM related teaching and learning opportunities. Second, that existing working theories mediate new working theories. Third, that by drawing on understandings of the child, of the concept the child is interested in, and of the child's understanding of the concept, teachers can act as mediating artefacts in young children's working theory development.

Young children develop and enrich working theories about the STEM domains. These working theories include knowledge, skills, and attitudes. Working theories involve the process of forming working theories, and the simultaneous outcome which is the working theory itself. Furthermore, children's working theories are interpretive frameworks, helping children to make sense of new information which leads to the development of further working theories. Working theories are an essential part of ECE. They provide children with a means to understand the world as they have experienced it, the skills to develop further and enriched working theories, and a foundation to filter new information through, and develop further working theories.

Teachers in ECE settings have important roles to play in fostering the development and enrichment of children's working theories. Understanding the child, the concept that the child is exploring, and understanding the child's understanding of the concept provides a foundation on which teachers can build teaching approaches that provide meaningful experiences. From

these experiences, teachers can select information and make it visible, then work with the children to make connections between their existing understandings and the new information. By doing so, teachers can foster the development and enrichment of the child's working theories.

Working theory development and the associated teaching approaches described above can be theorised using the lens of mediation. A mediational perspective highlights that teachers' perspectives of STEM in ECE mediates their involvement in STEM related teaching and learning opportunities. The same perspective highlights that existing working theories mediate the development of further working theories. Finally, a mediational perspective highlights that teaching approaches mediate the development and enrichment of children's working theories. Teaching approaches in themselves are mediated by understanding the child/ren, the concept that the child/ren is exploring, and by understanding the child/ren's understanding of the concept. Thus, understanding mediates teaching approaches, which mediates working theory development. Therefore, understanding mediates working theory development.

This is the concluding chapter of the thesis. I begin the chapter by providing a brief summary of the research, recapping the chapters. I then present and explain how I have addressed the three supporting research questions and the overarching research question. I then explain the significance of the research and the contribution that this thesis makes, which leads to the implications and recommendations resulting from this study. Next, I explain the limitations of this study, which leads to suggestions of possible further research. To finish, I conclude this chapter, and this thesis with some final thoughts.

Summary of the thesis structure

This section presents a brief and summary of the chapters of this thesis. I do this in consecutive order as below.

In chapter 1, I introduced, positioned, and justified the theme of the research. I explained that I was investigating young children's working theories about the STEM domains, and associated teaching approaches. Thus, I established two contexts for this research. First, it was carried out in ECE settings in Aotearoa New Zealand, and second, it was carried out within the context of the STEM domains. I positioned working theories as being a combination of knowledge, skills, and attitudes, and therefore as a notion that transcends the current focus on skills and competencies over knowledge. I argued that research about young children's working theories

in a STEM context is highly relevant. I presented the conceptual framework for this research which was underpinned by an interpretivist paradigm, under which I brought together sociocultural and social constructivist perspectives. This framework was important to the research as it recognised the engagement, interpretation, and meaning that people give to real-life experiences such as interactions with people, objects, materials, and resources. The conceptual framework was part of what led to the recognition and use of mediation to theorise the findings. I acknowledged that working theories are a notion that originated in New Zealand, have been picked up internationally, and have similarities to the notions of thinking, concept development, and knowledge building which are recognised internationally. I also explained that research about working theories has been published internationally. I then argued that the findings of this research have international significance, and contribute to understandings about the similar concepts of thinking, concept development, and knowledge building.

In chapter 2, I explained the research methodology and methods. I described and justified the nature of this research as an interpretivist, qualitative case study consistent with the conceptual framework. I explained that data generation drew on ethnographic approaches as I spent one morning per week as participant observer in each of two ECE centres for six months. I then explained the analysis process which focused on thematic analysis (Braun & Clarke, 2006, 2013), coupled with Yin's (2015) five stage process of compile, disassemble, reassemble, interpret, and conclude. I also described the process involved in developing the spiral of working theory development and SLC models throughout the research process. This development included refinement of the models during data analysis meaning that data analysis was deductive-inductive-abductive (Åsvoll, 2014).

Chapters 3, 4, and 5 addressed the three supporting research questions. In these chapters, I provided a critical literature review relevant to the research question, then presented findings and a discussion. I explain how these research questions were addressed later in this conclusion.

Chapter 6 explained the findings using the theoretical construct of mediation. I then wove the resultant explanations of the findings together to address and theorise the overarching research question for this study. I outline how I did this later in this chapter.

And finally, this current chapter highlights the significance and key outcomes of this research. Before I do so, next I return to the findings and the theorising from chapters 3-6.

Addressing the three research questions

This section addresses the research questions which were developed and investigated in this research and is effectively a brief summary of chapters 3-6. First, I provide a summary of the overarching research question. Next, I provide a brief summary of the three supporting research questions and how they were addressed. Finally, I conclude by outlining how I used the three supporting research questions to answer the overarching question.

From the initial critical literature review, I developed the overarching research question: How might working theories about STEM be developed, fostered and enriched in early childhood settings? Effectively, this question can be broken into four areas. The first two areas are the context: early childhood education, and STEM education. My interest in these two areas comes from my previous experience as an early childhood teacher, and before that, as an engineer. The third area is children's working theory development, and the fourth area is teaching approaches that foster and enrich working theory development. These two areas also come from my experience as an ECE teacher. I loved to listen to 3 and 4-year-old children's working theories, to challenge them and be involved in their development. It seemed that researching approaches teachers use to foster working theory development would be useful both to myself and to the wider sector.

Research question 1—the focus of chapter 3—is how do teachers perceive the place of STEM education within early childhood education? To proceed with the remainder of this research, it was necessary for me to generate empirical data about teacher perceptions, rather than assume that they were positive. The findings showed that teachers perceived that they had been involved in STEM related teaching and learning experiences, but had not identified or focused on STEM during those experiences or when writing later pedagogical documentation. In retrospect, teachers could identify STEM related learning when asked to. However, in-the-moment teaching, and later pedagogical documentation, focused on other learning areas such as dispositions and literacy. Teachers commonly held the view that STEM teaching and learning opportunities were available throughout the centres, but also noted that a role of the teacher was to make STEM visible to the children. Teachers did not consider that a lack of subject knowledge influenced their involvement in STEM related teaching and learning. Instead they shared that they drew on each other's expertise about areas they did not know about, or researched information using ICT either with the children or by themselves. The research also identified that other learning areas such as following children's interests, focusing

on dispositions and literacy constrained teachers from taking up potential STEM related teaching and learning opportunities. In chapter 6, I added the theoretical construct of mediation to explain the findings. The main argument pertaining to RQ1 is that teachers' perceptions towards STEM education mediate their involvement in STEM related teaching and learning opportunities. Therefore, teachers' perceptions of STEM education in ECE can be considered mediating artefacts.

Overall, the teachers held positive perceptions of STEM education in ECE. They could share positive STEM related experiences from their childhoods, identify STEM related teaching and learning when prompted, and perceived that they had the shared expertise and ICT available to find necessary subject information. Reflecting the complexity of teaching in ECE in New Zealand, I found that teachers were involved in teaching STEM amongst many other learning areas such as focusing on dispositions and literacy. The flexible, play-based philosophies espoused by the two centres in this study, coupled with the holistic and non-prescriptive nature of *Te Whāriki* provided a space for teachers to negotiate curriculum together with children and families. Acknowledging the complexity of ECE, and the many learning areas involved, STEM will not always be prioritised. Nevertheless, the positive perceptions teachers held towards STEM provided certainty to move forward with the research and with research questions 2 and 3 which I summarise next.

The second research question asked how might young children develop working theories related to the STEM domains. This question is addressed in chapter 4 and briefly summarised here. In the early stages of the initial literature review, I created the first versions of the spiral of working theory development model. I hoped the model might provide an understanding and representation of how children develop their working theories. Initial ideas for this model came from Bruner's (1977) spiral curriculum, Dewey's (1910) spiral of knowledge, and Wells' (1999) spiral of knowing. The model has undergone multiple iterations and refinements throughout the literature review, data analysis, and theorising stages of this research. The model has provided a framework for analysis, while simultaneously being modified as a result of the analysis. The same process occurred as I later theorised the findings, as the model guided my perspective on theory and was at the same time modified by the theory. The end result is a model which has been empirically tested and strengthened theoretically to represent how the children in this research developed their working theories.

The final version of the spiral of working theory development model includes four elements: understanding, experience, information, and making connections. In short, a young child holds initial understandings, has an experience, gains information from that experience, makes connections between their existing understandings and the new experience to form new understandings. As I have argued, in this thesis I have viewed working theories as a combination of knowledge, skills, and attitudes, and also as process, outcome, and interpretive framework. I have argued that working theories are more than understandings alone. Instead, I have argued they include all four elements of the spiral of working theory development model. Therefore, I have answered research question 2 by developing a model. The model is a spiral, illustrating that the process is iterative. One iteration might represent a small fraction of the total iterations that occur during any learning experience. In chapter 6, I added the theoretical construct of mediation to explain the findings. I therefore viewed the spiral of working theory development as a mediational model. In addition, I have viewed each of the four elements of the spiral model as mediators. As working theories incorporate all four elements of the spiral, working theories can also be viewed as a mediator. In this regard, existing working theories mediate the development of new working theories. As part of that process, new working theories might be formed, and the existing working theories that acted as mediators might be enriched. An understanding of working theory development led to the next research question which focuses on teaching approaches.

Research question 3 asked how might teachers foster and enrich children's working theories about the STEM domains. I addressed this question in chapter 5 and briefly summarise it here. During the literature review, I began to develop a model that could address the third research question. I called this model shared learning commitments (SLCs), drawing on Schaffer's (1992) notion of joint involvement episodes, and the notion of sustained shared thinking (Siraj-Blatchford et al., 2002) which is often abbreviated as SST. The SLC model has undergone substantial modification over the research process, and now also draws on the spiral of working theory development model. Again, the early model provided a framework for data analysis, and was simultaneously modified through the data analysis. The same process occurred during later theorising as the model provided a starting point for theorising, and was in turn modified through the theorising. Similar to the spiral of working theory development model, the end result is a model which has been empirically tested and strengthened theoretically. I overview the SLC model next.

The SLC model addresses research question 3 by modelling how teachers fostered and enriched young children's working theories. The model involves three outer elements that revolve around a central element. The central element is called understanding and consists of three aspects: understanding the child, understanding the concept the child is interested in, and understanding the child's understanding about the concept. The teacher makes meaning of their understanding to provide potentially meaningful experiences for the child. Within the experiences, the teacher selects potentially meaningful information and makes it visible to the child. The teacher then works with the child to make connections between the new information and the child's existing understandings, resulting in enriched working theories. Therefore, just as I addressed research question 2 by developing a model, I have addressed research question 3 by also developing a model which represents one way that a teacher can foster and enrich children's working theories. In chapter 6, I added the theoretical construct of mediation to explain the findings, and in particular the SLC model. I argued that the SLC model could be viewed from a mediational perspective, and therefore that teachers foster and enrich children's working theories about the STEM domains through mediation. I argued that teachers act as mediating artefacts that foster young children's working theory development. In terms of the SLC model, of particular importance to the mediating role, is understanding. Understanding leads to potentially meaningful responses in the form of experiences, the information teachers select to make visible in those experiences, and the connections that the teachers and children make.

In chapter 6, I theorised and explained the findings. I also wove the findings and theory together to address the overarching research question as I outline next.

Addressing the overarching question

A rigorous and critical process of melding literature, theory, data, and findings led to the identification of mediation (Daniels, 2015; Kozulin, 2003, 2018; Wertsch, 2007) as the key theoretical construct underpinning children's working theory development, and teachers' roles in that development. In chapter 6, I explained mediation as being a construct that theorises the relations between subject and object through an artefact (Cole, 1996). An artefact is a sign or tool that functions as a mediating agent enabling sense to be made of the social, cultural and historical contexts that are lived in (Kozulin, 2003). Importantly, and as I describe later in this section, an artefact can be physical or conceptual.

In chapter 6, I used the lens of mediation to theorise the findings of the three research questions. I argued that the teachers held dynamic perspectives of STEM education in ECE which acted as mediating artefacts in relation to their involvement in STEM teaching and learning opportunities. I described how working theories act as interpretive frameworks of new information, enabling sense to be made, and relations to be established between subject and object. I then argued that working theories, when viewed from this perspective can be viewed as mediating artefacts. I then explained that teachers' understandings were the key to the SLC model, and that the teachers' understandings mediated how they fostered and enriched children's working theories.

I wove these explanations together to address the overarching question which is how might working theories about STEM be developed, fostered and enriched in early childhood settings? In short, I addressed this question through the lens of mediation. I argued that teachers' perceptions of STEM act as mediating agents in relation to teachers' involvement in STEM related teaching and learning opportunities. I also argued that teaching approaches are mediated by teachers' understanding of the child, the concept, and the child's understanding of the concept. Finally, I argued that children's working theories are mediated both by the teaching approaches used, and by the existing working theories that the child holds. These are original and innovative findings and outcomes of significance to the ECE sector as I explain next.

Significance and contribution

This research has resulted in several significant contributions. These include contributions to the New Zealand and international scholarly literature about STEM education in ECE, about the notion of working theories and working theory development, and about teaching approaches related to working theory development. I explain these contributions next.

This research has investigated New Zealand ECE teachers' perceptions of STEM education. Consistent with prior literature, the teachers in my research reported positive attitudes towards STEM education in ECE. The teachers also viewed that STEM education provides children with basic knowledge and problem solving skills, aligning with the findings from Uğraş and Genç (2018). Furthermore, my research found that in ECE there are multiple learning areas for teachers to focus on, meaning that STEM related teaching and learning opportunities were not always prioritised, consistent with Kumtepe and Genc-Kumite's (2015) findings. This research

has therefore found consistencies with international literature as noted in chapter 3, adding a contribution from the New Zealand context.

This research makes an innovative and original contribution to the scholarly literature about working theories. First, this research takes a novel perspective of working theories as being a three-fold combination of process, outcome, and interpretive framework. The three-fold view brings together prior research from Davis and Peters (2011) who viewed working theories as a noun and verb, and Hedges and Jones (2012) who stated that working theories are "a framework for making sense of new experiences and ideas" (p. 36). The three-fold perspective brings together prior perspectives, to provide a broader, more complex view of working theories than has previously been theorised. In addition, I have argued that research related to working theories has implications for the notions of thinking, concept development, and knowledge building which are more readily recognised internationally than working theories. Therefore, the findings of this research have potential international significance.

This research also makes a new and significant contribution to scholarly literature, and to teachers' understandings of working theories by positioning them as mediators of further working theory development. This thinking builds on Bereiter's (2002) and Cole's (1996) work positioning mediating agents as purely conceptual and on Hedges (2012) suggestion that working theories might be considered implicit mediators. I have argued that each of the aspects of the three-fold view of working theories—process, outcome, and interpretive framework—can be considered as mediating agents. Therefore, when viewed as three-fold, working theories in themselves can be considered as mediating agents. This perspective on working theories offers a new and original lens for further research, for understanding working theory development, and for understanding and developing associated teaching approaches.

An original and innovative contribution has been made through the development and refinement of two models in this research. The first model, the spiral of working theory development represents the first time that the process of working theory development has been modelled. The model builds on Dewey's (1910) and Wells' (1999) work to provide a theoretical understanding of the multiple elements involved in developing and enriching working theories. The second model, the SLC also represents the first time the teaching process of fostering and enriching working theories has been modelled. This model builds on the work of Siraj-Blatchford et al. (2002), and Schaffer (1992) to represent how teachers fostered and enriched working theory development in this study. These models provide a new understanding

of children's working theory development, and how teachers can foster working theory development. The SLC model provides space within each element for teachers to develop strategies and techniques that are appropriate for the children in their context. Both models then offer a new contribution to scholarly literature, and also to teachers' understandings and practices.

Therefore, this research adds significant contributions to prior research and literature. It provides a New Zealand ECE context to STEM related research and literature. It builds on existing literature to provide a new perspective on working theories, and offers new and innovative models illustrating working theory development and teaching approaches. Because of this significance, there are associated implications which I discuss next.

Implications and recommendations

This thesis presents multiple implications and recommendations for teachers' professional learning, research, and policy. This section explains these implications and recommendations which are relevant to teaching practice, academic scholars, researchers, and policy makers.

Professional learning

There are many implications and recommendations related to ECE teaching practice arising from this study. Professional learning is required for teaching practice to change. Therefore, this section highlights the professional learning which could influence teacher practice. The professional learning could focus on STEM education, redressing the balance between working theories and dispositions, understanding the relationship between working theories and dispositions; using the two models to enhance teacher's understandings of working theories; and enhancing teachers' understandings of mediation in regards to working theory development. I explain these aspects next.

Findings from this study suggest that STEM related teaching and learning opportunities are not always prioritised over or with other learning areas. Yet STEM related learning could be included in the other areas that are prioritised, or alternatively, those areas could be included in STEM related learning. Professional development and initial teacher education might highlight and focus on the nature of ECE having multiple learning areas. A focus on the holistic nature of teaching and learning in ECE could potentially lead to an interweaving of STEM education into other areas of learning.

The notion of working theories, their development and how to teach them has been a problematic space in ECE. A focus on dispositions over working theories has led to a disproportionate tendency to highlight children's dispositions in teaching and assessment. Yet, working theories and dispositions are two sides of the same coin (Peters et al., 2018). Therefore, a rebalancing of understandings related to teaching and assessment is required to focus on both working theories and dispositions. Professional development and initial teacher education might enable deeper teacher subject knowledge about working theories. Deeper knowledge could enable teachers to more confidently engage in teaching and learning opportunities that highlight working theories.

As I have stated previously, working theories and dispositions are intertwined. A deeper understanding of the reciprocal relationship between working theories and dispositions could result in improved outcomes for young children. Working theories and dispositions each represent a unique perspective on young children's knowledge, skills, and attitudes. A focus on both working theories and dispositions in children's learning instead of working theories or dispositions alone could result in teaching, learning and planning that better encompasses children's developing knowledge, skills, and attitudes.

The spiral of working theory development model presents one way for teachers to understand how children develop working theories. The SLC model might also present one way for teachers to develop their understandings of how they could work with children to enrich their working theories. The SLC model is deliberately not a set of techniques or strategies, but rather a framework which could guide teachers to understand and form strategies and techniques which work best for the children in their context. Using the model as a basis, teachers might reflect on and develop strategies and techniques which are best appropriate for their settings and children. Therefore, the spiral of working theory development and SLC models could be used in initial teacher education and in professional development to extend teachers' understandings about how working theories develop and how they might enrich working theory development.

As I have stated, mediation is the key theoretical concept used to explain the findings of this thesis. From a teacher's perspective, mediation can be considered as understanding which in terms of this research has multiple meanings. First, understanding the STEM concepts that the children are interested in and are exploring. Second, understanding how working theories are developed and the teacher's role in working theory development. Third, understanding the

child/ren, and their understandings of the concept. Each of these aspects are complex undertakings requiring professional development. Professional development is also required to understand STEM concepts, working theory development and teachers' roles. In addition, time and opportunities are required for teachers to engage in reflective and critical dialogue about these understandings, to trial strategies and techniques, and to evaluate their effectiveness.

Research

This study also points to implications and recommendations for academics and researchers. First, the idea that teachers are faced with multiple learning areas in ECE offers opportunities for academics to reconsider initial teacher education programmes to address the tension between developing in-depth understandings, and the holistic nature of ECE teaching and learning. Second, the models and understandings of the theoretical explanation of mediation as underpinning working theory development might provide a basis for new insights into working theory development. As I explain later in this chapter, the models provide a starting point for further research.

Policy

Finally, the findings of this research offer implications for policymakers. First, for policymakers to fund and provide professional development and non-contact time for teachers related to working theory development about the STEM domains. Second, for policymakers to fund and provide non-contact time for teachers to engage in dialogue about STEM related working theories, to trial strategies and techniques, and to evaluate their effectiveness.

Therefore, the implications have multiple levels. The findings about teachers' perceptions of STEM, the two models developed throughout the research, and the theoretical explanation of mediation as underpinning working theory development and enrichment offer implications for teachers, academics, researchers, and policymakers. I now move on to discuss the limitations and further research opportunities that this study offers.

Limitations and further research

The nature of an interpretivist, qualitative case study in everyday settings can lead to rich understanding of real-world contexts. It can also present limitations. These limitations raise the possibility of further research which I discuss later in this section. Before that, I discuss the limitations from a methodological and theoretical perspective.

Using an interpretivist paradigm means that my interpretations form a key part of this research. I have been transparent about the research process, and have clarified my background and positioning as researcher. In this way, I have argued that the research is trustworthy. I acknowledge that my background and positioning has influenced my conceptual framework, the literature review, and the research process, including the methods used, the data I have chosen to generate, and my decisions about data analysis. I recognise that alternative positions to this research could have been taken.

The nature of my case study research, being exploratory and instrumental has also enabled in-depth and rich understandings of the settings and research questions to be formed. At the same time, I acknowledge that a case study investigating teacher and child interactions in two ECE centres cannot be assumed to represent all teacher-child interactions in all centres. However, as I have focused on a broad view of mediation, and foregrounded processes over content, I argue that this research has the potential to inform understandings about children's working theory development and associated teaching approaches beyond these two settings.

Being a new and original contribution to understandings about the notion of working theories, further research is a natural consequence of this study. Based on the key findings, the two models, and the underpinning theoretical construct of mediation, I expect that this research opens doors for further research. First, to address the limitations that I have raised, and second, to continue the investigation and exploration of working theories as a notion and how teachers might work with children to foster and enrich working theory development.

Similar research could be undertaken with younger children to investigate how they develop working theories in embodied ways as they might be pre-verbal. Research could investigate the appropriateness of the spiral of working theory development model for infants and toddlers. The research could also be undertaken in different settings which might have particular philosophical or cultural orientations. Further research could also be carried out that investigates working theory development that focuses on contexts other than STEM.

The two models that I have presented have been refined greatly during the research process. Each model could be considered as a new door which has been opened to provide a new perspective on the development of working theories about STEM, and the associated teaching approaches. Further theoretical perspectives of the models could be explored. In addition, further research could investigate each element of the models in more depth than this research

has. Therefore, this research could be thought of as a starting point for further research that investigates and refines the two models.

Final thoughts

I began this this research journey with an inkling about working theory development coupled with a passion to listen to, talk with, and to inspire children to develop their working theories about the world. Existing literature and prior research has inspired me to continue the journey as I have theorised and brought existing ideas together in new and exciting ways. Passionate teachers and fascinating children have engaged with me, and have enabled me to generate rich and wonderful data. Rigorous analysis, and difficult decision making (see chapter 2) has enabled me to make sense of the data and to form deep understandings about working theories and teaching approaches. And finally, further theorising and analysis has led to the key findings of this research: that mediation is a key theoretical concept that explains working theory development and associated teaching approaches; the spiral of working theories development model; and the shared learning commitments model. These models represent significant advances in understanding ways that children develop their working theories, and ways that teachers can foster and enrich children's working theories. The models offer potential value to enrich teachers' understandings, and could form the basis of further research. First, research that explores the models' usefulness in different contexts, and second, research that investigates the elements of each model in detail. Therefore, the findings of this research could inform current understandings, and inspire further research.

The notion of working theories began as a New Zealand based concept. However, due to the international attention that working theories has garnered, and the similarities that working theories share with the notions of thinking, concept development, and knowledge building this research holds important international implications. Deeper understandings, and modelling of working theories might provide deeper understandings and serve as a basis for modelling ways that working theories themselves, and thinking, concept development and knowledge building are developed.

This brings me back to the overarching research question: How might working theories about STEM be developed, fostered and enriched in early childhood centres? Teachers and children both develop, foster and enrich children's working theories. Teachers act as mediating agents by understanding children, understanding the concepts that children are exploring, and by

understanding children's understanding of those concepts. The teachers' understandings mediate their responses, which in turn mediate children's working theories. At the same time, children's working theories act as mediating agents and therefore mediate the development of their working theories.

As the proverb at the beginning of the chapter says: *Kua hua te marama: The moon is full, the cycle is completed*. (Mead & Grove, 2001). In saying that the cycle is completed, I hope that this thesis might be the beginning of many more cycles that add further strands to our tapestry of understanding about teaching and learning.

Appendices

Appendix A: Introductory letter for families

Epsom Campus
Gate 3, 74 Epsom Ave
Auckland, New Zealand
T +64 9 623 8899
W
education.auckland.ac.nz
The University of Auckland
Private Bag 92601
Symonds Street
Auckland 1135

Children's working theories about STEM subjects project

Kia ora koutou parents, caregivers, families and whānau

My name is Daniel Lovatt. I am a doctoral student at the University of Auckland. Until recently I have been a kindergarten teacher (and before that an electrical engineer). This year, an opportunity arose for me to undertake my doctoral studies which I am now doing.

This letter is to let you know that the [name removed] and [name removed], have kindly given me permission to carry out my research in your child's Centre. My research focuses on the approaches that teachers use to help children to develop working theories (ideas and thinking) about the STEM subjects (science, technology, engineering and maths). The research focuses on teachers but also includes children.

I plan to spend up to seven months in the Centre, observing teachers as they go about their everyday teaching. I will be making informal hand-written notes, and video-recording interactions between teachers and children. I will also carry out interviews with teachers. It is also possible, in fact likely, that some children might choose to interact with me. I will do my utmost to minimise any disruption to Centre routines and will help teachers where I can.

I give you my assurance that any notes I make during this time will be focused on the interactions between teachers and children. I will also be attempting to understand children's current and shifting working theories to see how they change, during and after interactions with teachers.

I can assure you that any reports, publications, or presentations developed from my research activity in the Centre will contain no specific and identifiable details about your children.

I look forward to meeting you and your children as I undertake the project. You will receive a formal invitation to participate in the project soon. I hope you will then say hello to me at the centre and ask me any questions you have about the project.

Many thanks, Daniel Lovatt, d.lovatt@auckland.ac.nz

The University of Auckland

Appendix B: Participant Information Sheets

B1: Centre Owner Participant Information Sheet

Epsom Campus
Gate 3, 74 Epsom Ave
Auckland, New Zealand
T +64 9 623 8899
W
education.auckland.ac.nz
The University of Auckland
Private Bag 92601
Symonds Street
Auckland 1135

Participant Information Sheet

(Centre owner/manager/organisation representative)

Title of Project: Creating knowledge together: Fostering and enriching children's working theories

My name is Daniel Lovatt. I am a student at the University of Auckland, and have had an interest in children's working theories[1] since I first began my teacher education in 2009. This research is part of my doctoral study, investigating how teachers might extend children's working theories about STEM (science, technology, engineering and mathematics) subjects. I am investigating the research question "*How might teachers foster and enrich children's working theories about STEM subjects through trialogy*[2]*?*"

I invite your Centre to participate in this research project. I am approaching you, the Centre owner/manager, for permission to access the Centre site as a potential setting for my project. The decision for your Centre to be involved or not in the study is voluntary. Should you agree, I am asking your permission to approach and invite all the teachers employed at the Centre to participate in the research. Subsequently, I will invite all families and children to participate in the research too. I seek your assurance that each teacher's decision to participate or not in the study will not affect her/his employment status in the Centre. I also seek your assurance that each family's decision for their children to participate or not, will not affect their relationship with teachers and your Centre. For your information, a copy of the introduction letter about my intended involvement in the Centre, and Participant Information Sheets and Consent Forms for teachers and families that outline the nature and extent of their involvement in the project are included with this letter.

[1] For this study, I view working theories as children's ideas and thinking formed through experiences, information and dialogue.
[2] For this study, I view trialogy as the development of new, or refinement of existing, working theories through problem solving and joint activities between children and teachers.

Your agreement to the Centre being involved will allow me to undertake my research at the Centre. If you agree, first I will arrange a time to discuss the project with your teaching staff at a time convenient to them, possibly during a staff meeting. During this discussion I will explain the nature of my investigation and teachers' and families' involvement. A Participant Information Sheet and Consent Form for teachers will then be made available for all teachers. For the study to proceed, I would need a minimum of two teachers and ten children as participants. Teachers would need to commit to approximately four hours of time outside their normal teaching hours to this study. Following two or more teachers' agreement to voluntarily participate, I will discuss the best way to approach and invite families to participate in the project, including by whom (e.g., the Centre administrator). I enclose a copy of the Participant Information Sheet, Consent Form and children's Assent Form intended to be distributed to families regarding their potential participation in the research. I also enclose a notice for families that could be displayed on a Centre noticeboard or given to each family. I intend to gain children's assent to participate. Each child who has been granted parental consent will have the opportunity to go through an Assent form with a teacher, their parents, and, if needed, with help from me. For very young children, signs of non-verbal assent will be looked for.

Pending your permission, I plan to spend up to seven months in your Centre as a participant-observer. This period will begin with eight half-days over a period of four weeks to familiarise myself with your context and to allow you, teachers, children, and their families when they are in the Centre, time to get familiar with me. Following this initial period, I wish to spend one half-day per week in your Centre, to observe, interact, video-record, photograph and write notes about participating teachers' interactions with the children. Names and identifiable details about children or teachers will not be included in any of my notes. I will respect the routines and policies of your Centre and be careful to minimise any disruption to teaching and learning interactions.

I also seek your permission to access relevant documentation pertaining to the Centre, such as curriculum documentation - learning stories and other documentation of children's STEM learning for those children who have consented to be part of this study. This might include making copies of, or photographing documentation.

I also seek your permission to use the Centre as a location to carry out two focus group meetings with the teachers who have agreed to be part of this study – one near the beginning of the research, and the other near the end of the research. In addition, I seek your permission to use the Centre to carry out individual teacher interviews. In the individual interviews, I plan to utilise selected parts of the video footage from the participant observations to engage teachers in conversation about the notion of everyday teaching strategies to foster and enrich children's working theories. I also intend to carry out home interviews at each of the teacher participants' homes who select to be home visited. Home interviews with teachers is a unique approach. Home interviews might provide insights into cultures, backgrounds, aspirations, beliefs and upbringing that influence teaching strategies. If required, I can be accompanied by one of my supervisors during the home interview. With participants' permission, I intend to audio-record the focus groups and individual interviews.

The nature of the research means that anonymity and confidentiality for the Centre and participants cannot be offered. However, the doctoral thesis, and teaching, presentations and publications that arise from the study, will be written and presented in a way that will protect the identity of your Centre and each participant. To minimise the risk that your Centre, teachers, children or families might be identified by outsiders to the Centre, pseudonyms will be used to replace their real names. In addition, I will request that the focus group participants keep any discussion from the focus group meetings confidential.

Please note that you have the right to withdraw access to the Centre at any time up until two weeks after completion of data gathering, without explanation.

Consent forms will be kept in a secure location for a period of six years in a locked cabinet in my supervisor's office (Associate Professor Helen Hedges) at the Faculty of Education, the University of Auckland. I will store copies of the interview transcripts, Centre documentation, field notes, video footage data, and electronic files in a secure location in the University of Auckland for at least six years, in accordance with University policy and guidelines. Audio files, video files and transcripts will be stored separately from any other identifying material.

Once the study has been completed, an overall summary of the findings will be provided to the Centre to offer to participating teachers and families. The summary is a small way for me to acknowledge and thank the Centre, teachers, and families for their participation, time and input into the study.

Thank you in anticipation for your time and help in making this study possible. If you have any questions or would like further information about the proposed research project please be in contact via email.

Kind regards,

Daniel Lovatt

Faculty of Education and Social Work, The University of Auckland

Private Bag 92601, Symonds St, Auckland 1150

d.lovatt@auckland.ac.nz

My main supervisor (and Head of School) is:	My second supervisor is:
Associate Professor Helen Hedges	**Dr. Rena Heap**
Faculty of Education and Social Work	Faculty of Education and Social Work
The University of Auckland	The University of Auckland
Private Bag 92601	Private Bag 92601
Symonds St, Auckland 1150	Symonds St, Auckland 1150
(09) 623 8899 ext. 48606	(09) 623 8899 ext. 48636
h.hedges@auckland.ac.nz	r.heap@auckland.ac.nz

For any concerns regarding ethical issues you may contact the Chair, the University of Auckland Human Participants Ethics Committee, at the University of Auckland, Research Office, Private Bag 92019, Auckland 1142. Telephone 09 373-7599 ext. 83711. Email: ro-ethics@auckland.ac.nz

APPROVED BY THE UNIVERSITY OF AUCKLAND HUMAN PARTICIPANTS ETHICS COMMITTEE ON 31/10/16 for (3) years, Reference Number 018057.

B2: Teacher Participant Information Sheet

Epsom Campus
Gate 3, 74 Epsom Ave
Auckland, New Zealand
T +64 9 623 8899
W
education.auckland.ac.nz
The University of Auckland
Private Bag 92601
Symonds Street
Auckland 1135

Participant Information Sheet

(Teachers)

Title of Project: Creating knowledge together: Fostering and enriching children's working theories

My name is Daniel Lovatt. I am a student at the University of Auckland, and have had an interest in children's working theories[3] since I first began my teacher education in 2009. This research is part of my doctoral study, investigating how teachers might extend children's working theories about STEM (science, technology, engineering and mathematics) subjects. I am investigating the research question "*How might teachers foster and enrich children's working theories about STEM subjects through trialogy*[4]*?*"

Your Centre owner/manager has given me permission to approach you as a potential participant in my study. Teachers are the focus of this study, however, data will also be collected from children to understand their developing working theories. Permission to conduct this research includes collecting data from observations and interviews, by audio-recording, video-recording, and photographing in your Centre. It also includes accessing and examining relevant Centre documentation related to the focus of my study, such as learning stories.

I plan to spend up to seven months in your Centre as a participant-observer. This period will begin with eight half-days over the first month to familiarise myself with your context and to allow you, other teachers, and the children time to become familiar with me. During the following six months, I will observe, interact, photograph, video-record and write notes about participating teachers' interactions with children when they are in the Centre. As my research focuses on teacher-child interactions, I will gather data about your interactions with participating children. My notes will not include any names or identifiable details about any

[3] For this study, I view working theories as children's ideas and thinking formed through experiences, information and dialogue.
[4] For this study, I view trialogy as the development of new, or refinement of existing, working theories through problem solving and joint activities between children and teachers.

of the teachers or children. I will respect the routines and policies of your Centre and be careful to minimise any disruption to teaching and learning interactions.

I may request access to relevant Centre documentation, such as samples of your learning stories or other curriculum documentation related to STEM. I also intend to carry out two focus group interviews, and individual interviews at the Centre with teachers who are willing to participate, and a home interview with the same teachers who are willing to participate. Home interviews with teachers is a unique approach. Home interviews might provide insights into cultures, backgrounds, aspirations, beliefs and upbringing that influence teaching approaches. I will be accompanied by one of my supervisors during the home interview. With your permission, I intend to audio-record the focus group meetings, and audio-record their individual interviews.

Once at least two teachers from your Centre have agreed to participate, I will seek advice from teacher participants about how best to approach families. I will then then seek the assistance of a staff member such as a Centre administrator to hand out, and collect Families Participant Information Sheets and Consent Forms regarding their child's potential participation in this study. The involvement of each family who agrees to participate will involve observations of their children at the Centre. The total amount of personal time outside your teaching commitments requested for the project is up to four hours over a period of approximately seven months.

I now invite you to participate in my study. Your Centre owner/manager has provided me with an assurance that your decision to participate or not will not affect your employment status, standing or relationship with the Centre. If you agree to participate, your involvement will entail the following:

- being observed by me as you interact with children and other consenting teachers. My focus will be on interactions between adults and children. My notes will exclude specific names or identifiable details of the teachers or children, however audio and video recordings will contain identifiable teachers and children. The audio and video will be transcribed and identifiers will be removed.

In addition, you can choose to participate in the following:

- two focus group meetings (up to 1 hour each), which will be audio-recorded, with me and other participating teachers;
- one individual interview (up to 1 hour) at the Centre, which will be audio-recorded with your permission. This interview will involve viewing video and reflecting on footage of selected teacher-child interactions. The audio-recording will be transcribed by me or a professional transcriber who will sign a confidentiality agreement. You will be offered the opportunity to review and edit the transcript of your individual interview for verification of content;
- one individual interview (up to 1 hour) at your home to discuss influences on your teaching. This will be audio-recorded with your permission. The interview might also include viewing video and reflecting on footage of selected teacher-child interactions. The audio-recording will be transcribed by me or a professional transcriber who will

sign a confidentiality agreement. You will be offered the opportunity to review and edit the transcript of your individual interview for verification of content;

Please feel free to email me if you have any questions about this project.

The nature of the research means that anonymity for the Centre and participants cannot be offered, and confidentiality cannot be guaranteed. However, the thesis that results, and any presentations and publications that arise from the study will be written in a way that will protect the identity of your Centre and each participant. Pseudonyms will be used to replace the real names of the Centre, teachers, and children. Names or identifiable details about children will not be included.

If you agree to participate in this research project and you are satisfied that all your questions have been answered, please complete the accompanying Consent Form and return it to the box provided at your Centre office, as soon as possible. Consent forms will be kept in a secure location for a period of six years in a locked cabinet in my supervisor's office (Associate Professor Helen Hedges) at the Faculty of Education, the University of Auckland. I will store copies of the interview transcripts, Centre documentation, field notes, video footage data, and electronic files in a secure location in the University of Auckland for at least six years, in accordance with University policy and guidelines. Audio files, video files and transcripts will be stored separately from any other identifying material.

Please note that you have the right to withdraw from the project at any time after the fieldwork has begun up until two weeks after completion of data gathering without providing an explanation. You also have the right to withdraw your data (excluding focus group data) up until two weeks after completion of data gathering without providing an explanation. Due to the focus group discussions involving multiple participants, you cannot withdraw your data from these discussions.

Once the study has been completed, an overall summary of the findings will be provided to the Centre to offer to participating teachers and families. The summary is a small way for me to acknowledge and thank the Centre, teachers, and families for their participation, time and input into the study.

Thank you in anticipation for your time and help in making this study possible. If you have any questions or would like further information about the proposed research project please be in touch.

Kind regards,

Daniel Lovatt

Faculty of Education and Social Work

The University of Auckland

Private Bag 92601

Symonds St, Auckland 1150

d.lovatt@auckland.ac.nz

My main supervisor (and Head of School) is:	My second supervisor is:
Associate Professor Helen Hedges	**Dr. Rena Heap**
Faculty of Education and Social Work	Faculty of Education and Social Work
The University of Auckland	The University of Auckland
Private Bag 92601	Private Bag 92601
Symonds St, Auckland 1150	Symonds St, Auckland 1150
(09) 623 8899 ext. 48606	(09) 623 8899 ext. 48636
h.hedges@auckland.ac.nz	r.heap@auckland.ac.nz

For any concerns regarding ethical issues you may contact the Chair, the University of Auckland Human Participants Ethics Committee, at the University of Auckland, Research Office, Private Bag 92019, Auckland 1142. Telephone 09 373-7599 ext. 83711. Email: ro-ethics@auckland.ac.nz

APPROVED BY THE UNIVERSITY OF AUCKLAND HUMAN PARTICIPANTS ETHICS COMMITTEE ON 31/10/16 for (3) years, Reference Number 018057

B3: Family Participant Information Sheet

Epsom Campus
Gate 3, 74 Epsom Ave
Auckland, New Zealand
T +64 9 623 8899
W
education.auckland.ac.nz
The University of Auckland
Private Bag 92601
Symonds Street
Auckland 1135

Participant Information Sheet

(Parents / Families / Caregivers)

Title of Project: Creating knowledge together: Fostering and enriching children's working theories

My name is Daniel Lovatt. I am a student at the University of Auckland, and have had an interest in children's working theories since I first began my teacher education in 2009. This research is part of my doctoral study which looks at how teachers might extend children's new ideas, and changing thinking and learning (or working theories) about STEM (science, technology, engineering and mathematics) subjects. I am investigating the research question "*How might teachers foster and enrich children's working theories about STEM subjects through problem solving and joint activities between children and teachers (or trialogy)?*" Your Centre owner/manager has given me permission to approach you as the parents/family of your/a child who is a potential participant in my study.

While teachers are the focus of this study, data collected will involve children in three ways too. First, I will record teachers' and children's interactions, second, I will observe children to try to understand their developing working theories, and third, I would like to access and examine relevant documentation including children's learning stories. Data will be collected from observations, photographs, audio and video-recording.

I plan to spend up to seven months in your Centre as a participant-observer. This period will begin with eight half-days over the first month to familiarise myself with the everyday routines and learning experiences in the centre; this also allows the children and teachers time to become familiar with me. Following this, for up to six months, I will observe, interact, photograph, video-record and write notes about participating teachers' interactions with children when they are in the Centre. My notes will not include any names or identifiable details about any of the teachers or children. However, video recordings will contain identifiable teachers and children, therefore the audio and video will be transcribed and all identifiers removed. I will absolutely respect the routines and policies of the Centre and be careful to minimise any disruption to teaching and learning interactions.

If you agree for your child to participate in this research, and your child indicates interest in this, I will provide an Assent Form for your child to go through (a sample of this form is attached). It is a very simple form, and allows your child to ask questions and make a decision about their involvement in the research. In addition, whenever I am collecting data I will also observe your child's body language, facial expressions and attitudes to gauge whether they are granting assent on a daily basis, and move away if necessary.

Please note that if you agree for your child to participate in this research, you have the right to withdraw from the project at any time after the fieldwork has begun up until two weeks after completion of data gathering without providing an explanation. You also have the right to withdraw specific, identifiable data of your child up until two weeks after completion of data gathering without providing an explanation.

The nature of the research means that anonymity for the Centre and participants cannot be offered, and confidentiality cannot be guaranteed. However, the thesis that results, and any presentations and publications that arise from the study will be written in a way that will protect the identity of your Centre and each participant. Pseudonyms will be used to replace the real names of the Centre, teachers, and children. Names or identifiable details about children will not be included.

If you agree for your child to participate in this research project and you are satisfied that all your questions have been answered, please complete the accompanying Consent Form and return it to the box provided at your Centre office, as soon as possible. Your Centre owner/manager has provided me with an assurance that your decision to participate or not will not affect yours or your child's relationships with the teachers or the Centre. If you choose for your child to not participate, I will take all practical steps to ensure that your child does not feel excluded as I gather data. This means that if approached, I will talk and interact with your child, however I will not include any of the interactions in my data collected and hence in this research project.

Consent forms will be kept in a secure location for a period of six years in a locked cabinet in my supervisor's office (Associate Professor Helen Hedges) at the Faculty of Education, the University of Auckland. I will store copies of the interview transcripts, Centre documentation, field notes, video footage data, and electronic files in a secure location in the University of Auckland for at least six years, in accordance with University policy and guidelines. Audio files, video files and transcripts will be stored separately from any other identifying material.

Once the study has been completed, an overall summary of the findings will be provided to the Centre to offer to participating teachers and families. The summary is a small way for me to acknowledge and thank the Centre, teachers, and families for their participation, time and input into the study.

Thank you in anticipation for your time and help in making this study possible. I am looking forward to getting to know the teachers and children here. If you have any questions or would like further information about the proposed research project please be in touch in person or by email.

Kind regards,

Daniel Lovatt

Faculty of Education and Social Work, The University of Auckland

Private Bag 92601, Symonds St, Auckland 1150

d.lovatt@auckland.ac.nz

My main supervisor (and Head of School) is:	My second supervisor is:
Associate Professor Helen Hedges	**Dr. Rena Heap**
Faculty of Education and Social Work	Faculty of Education and Social Work
The University of Auckland	The University of Auckland
Private Bag 92601	Private Bag 92601
Symonds St, Auckland 1150	Symonds St, Auckland 1150
(09) 623 8899 ext. 48606	(09) 623 8899 ext. 48636
h.hedges@auckland.ac.nz	r.heap@auckland.ac.nz

For any concerns regarding ethical issues you may contact the Chair, the University of Auckland Human Participants Ethics Committee, at the University of Auckland, Research Office, Private Bag 92019, Auckland 1142. Telephone 09 373-7599 ext. 83711. Email: ro-ethics@auckland.ac.nz

APPROVED BY THE UNIVERSITY OF AUCKLAND HUMAN PARTICIPANTS ETHICS COMMITTEE ON 31/10/16 for (3) years, Reference Number 018057

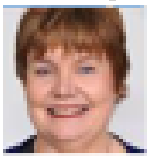
Epsom Campus
Gate 3, 74 Epsom Ave
Auckland, New Zealand
T +64 9 623 8899
W education.auckland.ac.nz
The University of Auckland
Private Bag 92601
Symonds Street
Auckland 1135

Children's assent sheet

(This form will be held for a period of 6 years)

Title of Project: Creating knowledge together: Fostering and enriching children's working theories

Researcher: Daniel Lovatt, with help from Helen Hedges and Rena Heap


My name is:_____

I have talked with my teacher about this research. Is it ok for Daniel to watch me learning, thinking, and playing with teachers and children?

Yes ☆ No ☆

(Please colour one star)

Is it ok for Daniel to write about me and to take videos of me?

Yes ☆ No ☆

On the back of this piece of paper could you please draw a picture of something you like to do here.

B4: Children’s Information Sheet

Children’s assent Information Sheet

Creating knowledge together: Fostering and enriching children’s working theories

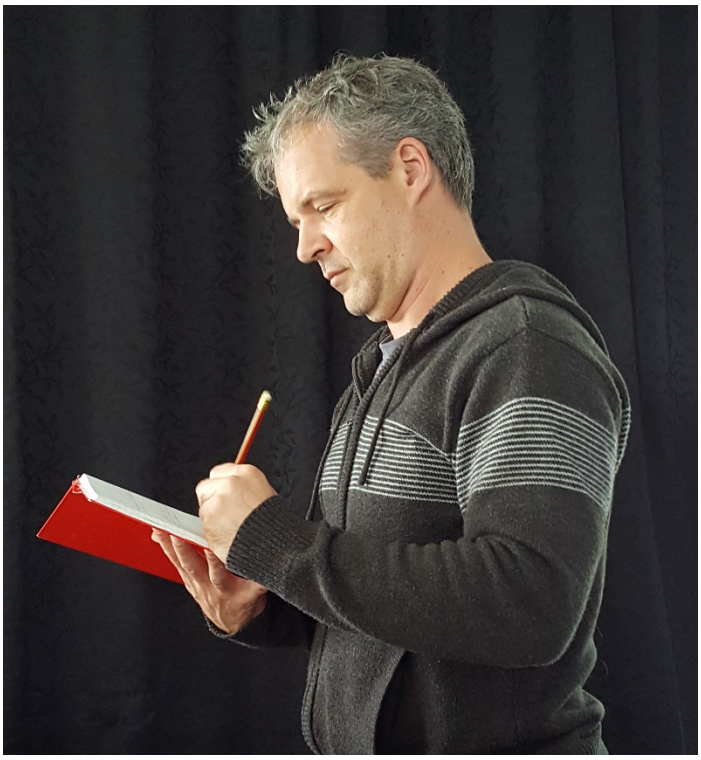
Daniel Lovatt, with help from Helen Hedges and Rena Heap

Hi, I’m Daniel

and I will be at your [removed] every Monday morning for a few months.

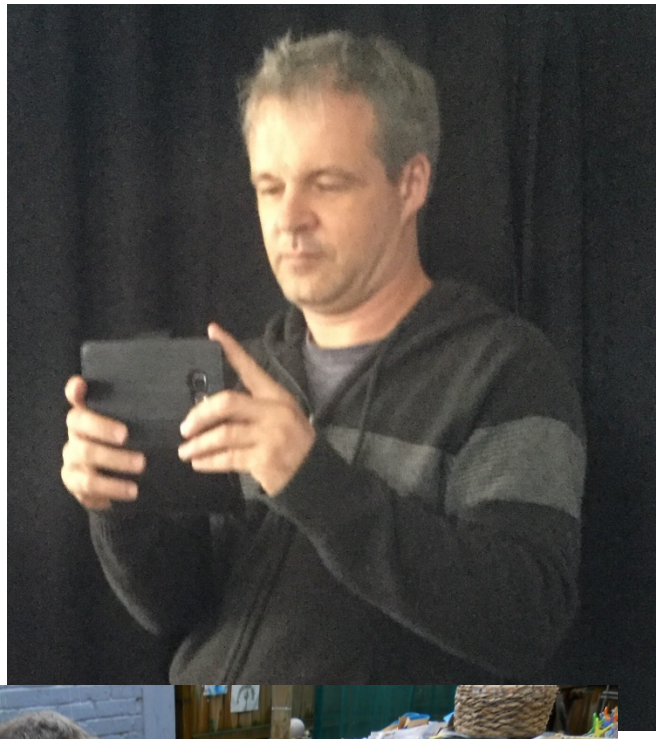
I would like to find out about your ideas and how you think that things work.

To find out, I might ask you questions and write down what you tell me



or video record you and

or take photos of things you are doing



your friends.

I would also like to find out how your teachers help you to find out about things. So I might also ask them questions, take photos of them and take video recordings of them while they are

working and playing with you.

Later on I will read my notes, look at the photos and watch the video recordings. Only me, Rena and Helen will look at these.

This is Rena, me and Helen. They are helping me.

I hope that by doing all these things I can help other teachers to help their children to have great ideas.

I have asked your parents if it's ok to talk with you and they said yes.

My university does not want me to use your real name when I talk and write about you. Would you like to choose another name for me to use?

If you don't like the way I am doing things, or if you don't want to talk with me or be recorded later on, please tell me and I will stop until you are ready again.

Appendix C: Participant Consent Forms

C1: Owner Consent Form

Epsom Campus
Gate 3, 74 Epsom Ave
Auckland, New Zealand
T +64 9 623 8899
W
education.auckland.ac.nz
The University of Auckland
Private Bag 92601
Symonds Street
Auckland 1135

Consent Form

(Centre owner/manager/organisation representative)

(This form will be held for a period of 6 years)

Title of Project: Creating knowledge together: Fostering and enriching children's working theories

I have been given and understood an explanation of this research project. I have had an opportunity to ask questions and have them answered.

- I consent to the researcher having access to the Centre for this project.
- I give permission to the researcher to approach the teachers employed at the Centre, and the families whose children attend, with the assistance of teachers or a Centre administrator, to be involved in the research project.
- I give my assurance that staff participation or non-participation in the project will not affect their status in the Centre and that parents' decisions for children to participate or not, will not affect their or their child/ren's relationship with the Centre.
- I agree to the researcher taking field notes, photographing and undertaking video-recording observations in the Centre pending consent from the individual teachers and assent from individual children.
- I agree to the researcher audio-recording individual interviews in the Centre, pending consent from the individual teachers.
- I agree to the researcher audio-recording the two focus group meetings, pending consent from individual teachers.
- I agree to the researcher having access to Centre documentation pertinent to the study (e.g., curriculum planning documentation).
- I understand that I can withdraw access to the Centre or documentation at any time until two weeks after completion of data gathering without explanation. Should I choose to withdraw the Centre's involvement, all data gathered about the Centre will be destroyed soon after the decision has been made.

- I understand that the data and findings will be used for the researcher's doctoral thesis, teaching, presentations and publications arising from the research.
- I understand that complete confidentiality cannot be guaranteed, but that to minimise the risk of being identified, pseudonyms will be used to replace the real names of the Centre, teachers, and families. Children's names and identifiable details will not be included.
- I understand that data will be kept securely, for six years and then destroyed.
- I understand that a summary of the research findings will be provided to the Centre which the Centre can then offer to participating teachers and families.

Signed:

Name:

Date:

APPROVED BY THE UNIVERSITY OF AUCKLAND HUMAN PARTICIPANTS ETHICS COMMITTEE ON 31/10/2016 for (3) years, Reference Number 018057

C2: Teacher Consent Form

Epsom Campus
Gate 3, 74 Epsom Ave
Auckland, New Zealand
T +64 9 623 8899
W
education.auckland.ac.nz
The University of Auckland
Private Bag 92601
Symonds Street
Auckland 1135

Consent Form

(Teachers)

(This form will be held for a period of 6 years)

Title of Project: Creating knowledge together: Fostering and enriching children's working theories:

I have been given and understood an explanation of this research project. I have had an opportunity to ask questions and have them answered.

- I agree to take part in this project.
- I understand that participation in this project is voluntary.
- I understand that the research is focused on interactions between teachers and children.
- I understand that my decision to participate or not in the project will not affect my employment status, standing, or relationship with the Centre.
- I understand that the Centre owner/manager has granted the researcher permission to access relevant Centre documentation such as learning stories and other curriculum documentation.
- I understand that I may be observed, photographed and video-recorded while interacting with children.
- I agree to maintain confidentiality of information shared at the focus group interview and staff meeting.
- I understand that I can withdraw from the project anytime up until two weeks after completion of data gathering without giving a reason.
- I understand that I can withdraw my data (excluding focus group data) up until two weeks after completion of data gathering without giving a reason.
- I understand that data will be kept securely, for six years and then destroyed.
- I understand that the data and findings will be used for the researcher's doctoral thesis, teaching, presentations and publications arising from the research.

- I understand that all efforts will be made to maintain my right to confidentiality, and to minimise the risk of being identified, pseudonyms will be used to replace my real name(s). I also understand that no names or identifiable details of children will be included.
- I understand that I will have an opportunity to review and edit a copy of my interview transcript(s).
- I **agree/disagree** (please indicate by circling the appropriate term) to participate and to be audio-recorded in the focus group meetings.
- I **agree/disagree** to participate and to be audio-recorded in an individual interview at the Centre.
- I **agree/disagree** to participate and to be audio-recorded in an individual interview at my home.

- I **would/would not** like a copy of a summary of the research findings.

Signed:

Name:

Date:

APPROVED BY THE UNIVERSITY OF AUCKLAND HUMAN PARTICIPANTS ETHICS COMMITTEE ON 31/10/16 for (3) years, Reference Number 018057

C3: Family Consent Form

Epsom Campus
Gate 3, 74 Epsom Ave
Auckland, New Zealand
T +64 9 623 8899
W
education.auckland.ac.nz
The University of Auckland
Private Bag 92601
Symonds Street
Auckland 1135

Consent Form

(Parents / Families)

(This form will be held for a period of 6 years)

Title of Project: Creating knowledge together: Fostering and enriching children's working theories

I have been given and understood an explanation of this research project. I have had an opportunity to ask questions and have them answered.

- I agree for my child/ren to take part in this project. I understand that this involves observations recorded through video-recording, photography and written field notes.
- I understand that I can withdraw identifiable data about my child/ren from the project any time up until two weeks after completion of data gathering without giving a reason.
- I understand that I can withdraw my child/ren from the project at any time up until two weeks after completion of data gathering without giving a reason.
- I understand that the Centre will be provided with access to a summary of the research findings.
- I understand that the data and findings will be used for presentations and publications arising from the research and for teaching purposes.
- I understand that the Centre Manager has given an assurance that my child's/ children's participation or non-participation will have no effect on my or my child's/ children's relationship with the Centre.

Name/s of parent/guardian:_____

Name of child/ren:_____

Signed:_____

Name:_____ Date:_____

APPROVED BY THE UNIVERSITY OF AUCKLAND HUMAN PARTICIPANTS ETHICS COMMITTEE ON 31/10/16 for (3) years, Reference Number 018057

Appendix D: Children's Assent Form

Epsom Campus
Gate 3, 74 Epsom Ave
Auckland, New Zealand
T +64 9 623 8899
W
education.auckland.ac.nz
The University of Auckland
Private Bag 92601
Symonds Street
Auckland 1135

Children's assent sheet

(This form will be held for a period of 6 years)

Title of Project: Creating knowledge together: Fostering and enriching children's working theories

Researcher: Daniel Lovatt, with help from Helen Hedges and Rena Heap

My name is:_____

I have talked with my teacher about this research. Is it ok for Daniel to watch me learning, thinking, and playing with teachers and children?

Yes ☆ (Please colour one star) No ☆

Is it ok for Daniel to write about me and to take videos of me?

Yes ☆ No ☆

On the back of this piece of paper could you please draw a picture of something you like to do here.

APPROVED BY THE UNIVERSITY OF AUCKLAND HUMAN PARTICIPANTS ETHICS COMMITTEE ON 31/10/16 for (3) years, Reference Number 018057

Appendix E: Focus group questions

E1: Focus group 1 questions

Indicative focus group 1 questions

Title of Project: Creating knowledge together: Fostering and enriching children's working theories

Researcher/interviewer: Daniel Lovatt

Saturday 8th April 2017 9-10 (one hour)

Question	**Mins**	**RQ**
Introductions and thanks for participating in this study and focus group	2	
Please introduce yourself and describe a time in your early childhood where you were engaged in science, technology, engineering or maths. Me construction the house with dad	10	General
I'd like to start with the idea of working theories. What do you understand a working theory to be? (So then is everything a WT and is it the same as thinking?)	5	2
Can you tell me some examples of your children's working theories, particularly how you noticed them, and what you did to respond?		2
My research is focusing on how teachers might foster and enrich children's working theories. Could you give me some examples of how you foster or enrich your children's working theories? (Are there better words?)		3, Main
I'd like to move on to focus more about STEM now. What do you understand STEM to actually be? (and in the context of ece) Could you please share some examples of children's interests and learning about STEM?	5	1
I'm interested to hear you views on the place of STEM in early childhood education		1
Tell me about the areas that STEM and Te Whāriki might have in common? Do you have any examples from your children?	5	1
How do you feel about teaching and learning about the STEM subjects with your children? …What approaches do you use?	5	3
What do/might you do if a child is interested in something that is related to STEM but you don't know much about it?	5	3
Can you tell me about a time when you responded to a child's interest in a STEM related topic such as bees… (or whatever has come up). What knowledge did you have or access? Were there any challenges in responding?	5	1, 3
Tell me about the working theories about STEM subjects have you noticed?	5	2

In what ways have you worked to extend children's working theories about STEM subjects? (Probe for examples)	5	2

Thank the participants for their time. Remind them that the interview will be transcribed by me or someone who has signed a university-approved confidentiality agreement.

E2: Focus group 2 questions

Indicative focus group 2 questions

Title of Project: Creating knowledge together: Fostering and enriching children's working theories

Researcher/interviewer: Daniel Lovatt

Saturday 27th January 2018 10-11 (one hour)

Question	Mins	RQ
Introductions and thanks for participating in this study and focus group	2	
How has your thinking about STEM changed during the last year	10	1
Are there particular aspects of STEM which are easier to focus on and if so which?	5	1
Can you tell me about any particular activities or experiences where you have deliberately set out to focus on STEM?		1
Are there any particular areas that the children seem to explore and develop working theories about STEM more than others?		2
I'm interested in the idea of noticing, recognising and responding to children's working theories about STEM. Can you give me some examples of when this has happened and the approaches you have used.		3
I can see a tension between teachers holding content knowledge about STEM domains versus or and learning together with the children. What are your thoughts about this?		3
If appropriate and we have time, discuss co-constructing knowledge together with the children	5	3
If appropriate and we have time, discuss the notion of mediating information with the children	5	3
Jungle Gym video		
What working theories about STEM do you think the children might be developing here?		2
What are the teaching approaches used that enable something like this to happen?		3
Then move on to the presentation theorising my study and ask for comments about the spiral and SLC		4

Thank the participants for their time. Remind them that the interview will be transcribed by me or someone who has signed a university-approved confidentiality agreement.

Appendix F: Individual interview questions

Indicative questions for Teacher interview

Title of Project: Creating knowledge together: Fostering and enriching children's working theories

Researcher/interviewer: Daniel Lovatt

12th October 2017 (one hour)

Question	Mins	RQ
Introduction and thanks for participating in this study and interview	2	
Please share with me the learning story example that you have brought documenting children's working theories about STEM. Why did you choose to select this curricular event? And document this topic/these WTs?	10	1,2
What challenges or constraints have you experienced about documenting children's WTs about STEM.	5	3
Share the video footage. Can you please tell me about your thinking while this was going on? What did you consider your role was here? What were your intentions? Why did you choose to engage in this? What ongoing learning occurred? What might you do differently next time? What do you think the children were thinking? What do you think the children were really interested in?	10	1,3
I'm interested to hear your views on the place of STEM in early childhood education	3	1
What do you consider your role to be regarding teaching STEM and WTs?	5	3
Where does the environment and resources fit into this?		
Are there particular strategies or responses that you might use to respond to, foster, and enrich children's working theories about STEM? What have you noticed that other teachers do and/or use?	5	3
How do you decide when to engage with children in their activities and experiences?	5	3
Tell me about how your thinking regarding STEM and WTs might have changed over this last 6 months? What has participating in the project made you think about more?	5	1
What particular STEM areas/domains do you think children might be drawn more towards? Why do you think this might be the case? (water trough, space, dinosaurs, baking?)	5	2
Can you please tell me some definite examples of S, T, E, M learning that you have noticed the children involved in (only if this hasn't been teased out earlier)	5	2

Thank teacher for their time. Remind her that the interview will be transcribed by me or someone who has signed a university-approved confidentiality agreement.

References

Agee, J. (2009). Developing qualitative research questions: A reflective process. *International Journal of Qualitative Studies in Education, 22*(4), 431-447. doi:10.1080/09518390902736512

Andria, L. (2019). STEAM + Research = STREAM centres. *Knowledge Quest, 48*(2), 54-61.

Applefield, J., Huber, R., & Moallem, M. (2000). Constructivism in theory and practice: Towards a better understanding. *The High School Journal, 84*(2), 35-53.

Areljung, S., & Kelly-Ware, J. (2017). Navigating the risky terrain of children's working theories. *Early Years, 37*(4), 370-385. doi:10.1080/09575146.2016.1191441

Åsvoll, H. (2014). Abduction, deduction and induction: Can these concepts be used for an understanding of methodological processes in interpretative case studies? *International Journal of Qualitative Studies in Education (QSE), 27*(3), 289-307. doi:10.1080/09518398.2012.759296

Bagiati, A., & Evangelou, D. (2015). Engineering curriculum in the preschool classroom: The teacher's experience. *European Early Childhood Education Research Journal, 23*(1), 112-128. doi:10.1080/1350293X.2014.991099

Bereiter, C. (2002). *Education and mind in the knowledge age*. Mahwah, N.J: L. Erlbaum Associates.

Berk, L., & Winsler, A. (1995). *Scaffolding children's learning*. Washington, DC: National Association for the Education of Young Children.

Blackley, S., & Howell, J. (2015). A STEM narrative: 15 years in the making. *Australian Journal of Teacher Education, 40*(7), 102-112. doi:10.14221/ajte.2015v40n7.8

Blaikie, N. (2004). Interpretivism. In M. S. Lewis-Beck, A. Bryman, & T. F. Liao (Eds.), *The Sage encyclopedia of social science research methods* (pp. 509-510). Thousand Oaks, CA: Sage. doi:10.4135/9781412950589.n422

Bogdan, R. C., & Biklen, S. K. (2007). *Qualitative research for education: An introduction to theories and methods* (5th ed.). Boston, MA.: Pearson.

Bourke, R., & Loveridge, J. (2013). Exploring informed consent and dissent through children's participation in educational research. *International Journal of Research & Method in Education, 37*(2), 151-165. doi:10.1080/1743727X.2013.817551

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77-101. doi:10.1191/1478088706qp063oa

Braun, V., & Clarke, V. (2013). *Successful qualitative research: A practical guide for beginners*. London, UK: Sage.

Brenneman, K., Lange, A., & Nayfeld, I. (2019). Integrating STEM into preschool education: Designing a professional development model in diverse settings. *Early Childhood Education Journal, 47,* 15-28. doi:10.1007/s10643-018-0912-z

Brinkmann, S. (2018). The interview. In N. Denzin & Y. Lincoln (Eds.), *The Sage handbook of qualitative research* (5th ed., pp. 576-599). Thousand Oaks, CA: Sage.

Bruner, J. S. (1977). *The process of education*. Cambridge, MA: Harvard University Press.

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

Buntting, C., Jones, A., McKinley, L., & Gan, M. (2013). *Consultant report securing Australia's future STEM: Country comparisons. STEM initiatives and issues in New Zealand*. Melbourne, Australia: Australian Council of Learned Academies.

Bybee, R. W. (2013). *The case for STEM education: Challenges and opportunities*. Arlington, VA: National Science Teachers Association.

Campbell, C., & Cutter-Mackenzie, A. (2015). Environmental education in natural play space. In C. Campbell, W. Jobling, & C. Howitt (Eds.), *Science in early childhood* (2nd ed., pp. 148-167). Melbourne, Australia: Cambridge University Press.

Campbell, C., & Howitt, C. (2015). The place of science in the early years. In C. Campbell, W. Jobling, & C. Howitt (Eds.), *Science in early childhood* (2nd ed., pp. 7-13). Melbourne, Australia: Cambridge University Press.

Campbell, C., Jobling, W., & Howitt, C. (Eds.). (2015). *Science in early childhood* (2nd ed.). Melbourne, Australia: Cambridge University Press.

Carr, M. (2001). Let me count the ways. Analysing the relationship between the learner and everyday technology in early childhood. *Research in Science Education*, 31, 29–47. doi:10.1023/A:1012654110604

Carr, M., & Lee, W. (2012). *Learning stories: Constructing learner identities in early education*. London, UK: Sage.

Carr, M., & Lee, W. (2019). *Learning stories in practice*. London, UK: Sage.

Cherrington, S., & Loveridge, J. (2014). Using video to promote early childhood teachers' thinking and reflection. *Teaching and Teacher Education, 41*, 42-51. doi:10.1016/j.tate.2014.03.004

Claxton, G. (1990). *Teaching to learn: A direction for education*. London, UK: Cassell.

Claxton, G. (2015). The development of learning power: A new perspective on child development and early education. In S. Robson & S. Flannery-Quinn (Eds.), *The*

Routledge international handbook of young children's thinking and understanding (pp. 367-376). Abingdon, UK: Routledge.

Cohen, L., Manion, L., & Morrison, K. (2013). *Research methods in education* (7th ed.). Florence, Italy: Routledge.

Cole, M. (1996). *Cultural psychology: A once and future discipline*. Cambridge, MA: Harvard University Press.

Conner, L. (2013). Could your school have a STEM emphasis? *NZ Science Teacher, 132*, 15-17.

Cooper, M., Hedges, H., Lovatt, D., & Murphy, T. (2013). Responding authentically to Pasifika children's learning and identity development: Hunter's interests and funds of knowledge. *Early Childhood Folio, 17*(1), 6-11.

Cooper, L., Johnston, J., Rotchell, E., & Woolley, R. (2010). *Knowledge and understanding of the world*. London, UK: Continuum International.

Cooper, M., Lovatt, D., & Hedges, H. (2015). Curriculum for very young children: Challenging perceptions. In J. Morgan (Ed.), *The 21st Century Curriculum?* Auckland, New Zealand: Edify.

Creswell, J. W. (2013). *Qualitative inquiry & research design: Choosing among five approaches* (3rd ed.). Thousand Oaks, CA: Sage.

Creswell, J. W. (2014). *Research design: Qualitative, quantitative, and mixed methods approaches* (4th ed.). Thousand Oaks, CA: Sage.

Creswell, J. W., & Creswell, J. (2018). *Research design: Qualitative, quantitative. and mixed methods approaches* (5th ed.). Thousand Oaks, CA: Sage.

Creswell, J., & Guetterman, T. (2019). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research* (6th ed.). Saddle River, NJ: Pearson.

Crotty, M. (1998). *The foundations of social research: Meaning and perspective in the research process*. Sydney, Australia: Allen & Unwin.

Cullen, J., Hedges, H., & Bone, J. (2011). Planning, undertaking and disseminating research in early childhood settings: An ethical framework. In S. Callan & M. Reed (Eds.), *Work-based research in the early years* (pp. 121-134). London, UK: Sage.

Cunningham, C. M., & Higgins, M. (2014). Engineering for everyone. *Educational Leadership, 72*(4), 42-47.

Cutter-Mackenzie, A., Edwards, S., & Widdop Quinton, H. (2015). Child-framed video research methodologies: Issues, possibilities and challenges for researching with children. *Children's Geographies, 13*(3), 343-356. doi:10.1080/14733285.2013.848598

Daniels, H. (2015). Mediation: An expansion of the socio-cultural gaze. *History of the Human Sciences, 28*(2), 34-50. doi:10.1177/0952695114559994

Davis, K., & McKenzie, R. (2017). *Children's working theories about identity, language and culture: O faugamanatu a fanau e sa'ili o latou fa'asinomaga, gagama ma aganu'u, final report.* Wellington, New Zealand: Teaching and Learning Research Initiative. Retrieved from www.tlri.org.nz/sites/default/files/projects/TLRI%20Summary_Davis%20for%20web.pdf

Davis, K., & Peters, S. (2011). *Moments of wonder, everyday events: Children's working theories in action final report*. Wellington, New Zealand: Teaching Learning Research Initiative. Retrieved from www.tlri.org.nz/moments-wonder-everyday-events-how-are-young-children-theorising-and-making-sense-their-world/

Davis, K., & Peters, S. (2012). Exploring learning in the early years: Working theories, learning dispositions and key competencies. In B. Kaur (Ed.), *Understanding teaching and learning: Classroom research revisited* (pp. 171-182). Rotterdam, Netherlands: Sense Publishers.

DeJarnette, N. K. (2012). America's children: Providing early exposure to STEM (science, technology, engineering and math) initiatives. *Education, 133*(1), 77-84.

Denzin, N. K., & Lincoln, Y. S. (Eds.). (2002). *The qualitative inquiry reader*. Thousand Oaks, CA: Sage.

Dewey, J. (1910). *How we think*. Boston, MA: Heath & Co.

Dierking, L., & Falk, J. (2016). 2020 vision: Envisioning a new generation of STEM learning research. *Cultural Studies of Science Education, 11*(1), 1-10. doi:10.1007/s11422-015-9713-5

Dockett, S., Perry, B., & Kearney, E. (2013). Promoting children's informed assent in research participation. *International Journal of Qualitative Studies in Education, 26*(7), 802-828. doi:10.1080/09518398.2012.666289

East, M., & Tolosa, C. (2015). The STEM revolution: What places for languages other than English? In J. Morgan (Ed.), *The 21st century curriculum?* (pp. 17-30). Auckland, New Zealand: Edify.

Eder, D., & Corsaro, W. (1999). Ethnographic studies of children and youth: Theoretical and ethical issues. *Journal of Contemporary Ethnography, 28*(5), 520-531. doi:10.1177/089124199129023640

Education Review Office. (2019). *Te Whāriki (2017): Awareness towards implementation*. Wellington, New Zealand: New Zealand Government.

English, L. D. (2016). STEM education K-12: Perspectives on integration. *International Journal of STEM Education, 3*(3), 1-8. doi:10.1186/s40594-016-0036-1

English, L. D., & Moore, T. J. (2018). *Early engineering learning*. Singapore: Springer.

Fleer, M. (2009). Supporting scientific conceptual consciousness or learning in 'a roundabout way' in play-based contexts. *International Journal of Science Education, 31*(8), 1069-1089. doi:10.1080/09500690801953161

Fleer, M. (2009a). Understanding the dialectical relations between everyday concepts and scientific concepts within play-based programs. *Research in Science Education, 39*, 281-306. doi:10.1007/s11165-008-9085-x

Fleer, M. (2010). *Early learning and development: Cultural-historical concepts in play*. Melbourne, Australia: Cambridge University Press.

Fleer, M. (2016). *Technologies for children*. Melbourne, Australia: Cambridge University Press.

Fleer, M., & Raban, B. (2006). A cultural-historical analysis of concept formation in early education settings: Conceptual consciousness for the child or only the adult? *European Early Childhood Research Journal, 14*(2), 69-80. doi:10.1080/13502930285209921

Flewitt, R. (2005). Conducting research with young children: Some ethical considerations. *Early Child Development and Care, 175*(6), 553-565. doi:10.1080/03004430500131338

French, L. A., & Woodring, S. D. (2013). Science education in the early years. In O. N. Saracho & B. Spodek (Eds.), *Handbook of research on the education of young children* (3rd ed., pp. 179-196). New York, NY: Routledge.

Gallas, K. (1995). *Talking their way into science: Hearing children's questions and theories, responding with curricula*. New York, NY: Teachers College Press.

Gillespie, A., & Zittoun, T. (2010). Using resources: Conceptualizing the mediation and reflective use of tools and signs. *Culture & Psychology, 16*(1), 37-62. doi:10.1177/1354067X09344888

Ginsburg, H. P., & Amit, M. (2008). What is teaching mathematics to young children? A theoretical perspective and case study. *Journal of Applied Developmental Psychology, 29*(4), 274-285. doi:10.1016/j.appdev.2008.04.008

Given, L. M. (2008). *The Sage encyclopedia of qualitative research methods*. Thousand Oaks, CA: Sage. doi:10.4135/9781412963909

Gjems, L. (2013). Teaching in ECE: Promoting children's language learning and cooperation on knowledge construction in everyday conversations in kindergarten. *Teaching and Teacher Education: An International Journal of Research and Studies, 29*, 39-45. doi:10.1016/j.tate.2012.08.008

González, N., Moll, L.C., & Amanti, C. (2005). *Funds of knowledge: Theorizing practices in households, communities, and classrooms*. New York, NY: Lawrence Erlbaum Associates.

Guba, E. G., & Lincoln, Y. (1989). *Fourth generation evaluation.* Newbury Park, CA: Sage.

Gunn, A. C. (2015). Research work as curriculum work in New Zealand early childhood settings: What should be taught and learned? *Journal of Pedagogy, 6*(2), 103-117. doi:10.1515/jped-2015-0016

Hallström, J., Elvstrand, H., & Hellberg, K. (2015). Gender and technology in free play in Swedish early childhood education. *International Journal of Technology and Design Education*, *25*(2), 137-149. doi:10.1007/s10798-014-9274-z

Hammersley, M., & Atkinson, P. (2019). *Ethnography: Principles in practice* (4th ed.). London, UK: Routledge.

Hargraves, V. (2011). *Supporting children's working theories in early childhood education: What is the teacher's role?* (Unpublished master's thesis). Auckland University of Technology: Auckland, New Zealand.

Hargraves, V. (2013). Teaching practices to support children's construction of knowledge: Working theories in early childhood education. In A. Grey & B. Clark (Eds.), *Ngā hurihanga ako kohungahunga: Transformative teaching practices in early childhood education* (pp. 49-60). Auckland, New Zealand: Pearson.

Haworth, P., Cullen, J., Simmons, H., Schimanski, L., McGarva, P., & Woodhead, E. (2006). *The flight of our kite: The Wycliffe Nga Tamariki kindergarten story*. Wellington, New Zealand: Ministry of Education.

Hedegaard, M. (2007). The development of children's conceptual relation to the world, with focus on concept formation in preschool children's activity. In H. Daniels, M. Cole, & J. V. Wertsch (Eds.), *The Cambridge companion to Vygotsky* (pp. 246-275). Cambridge, MA: Cambridge University Press. doi:10.1017/CCOL0521831040.011

Hedges, H. (2008). 'Even when we're big we'll still be friends': Working theories in children's learning. *Early Childhood Folio*, *12*, 2-6.

Hedges, H. (2011). Connecting ‘snippets of knowledge’: Teachers’ understandings of the concept of working theories. *Early Years: An International Journal of Research and Development*, *31*(3), 271-284. doi:10.1080/09575146.2011.606206

Hedges, H. (2012). Vygotsky's phases of everyday concept development and the notion of children's “working theories”. *Learning, Culture and Social Interaction*, *1*(2), 143-152. doi:10.1016/j.lcsi.2012.06.001

Hedges, H. (2014). Young children’s ‘working theories’: Building and connecting understandings. *Journal of Early Childhood Research*, *12*(1), 35-49. doi:10.1177/1476718X13515417

Hedges, H. (2014a). Children's content learning in play provision: Competing tensions and future possibilities. In L. Brooker, M. Blaise, & S. Edwards (Eds.), *The Sage handbook of play and learning in early childhood* (pp. 192-203). London, UK: Sage.

Hedges, H. (2015). Sophia's funds of knowledge: Theoretical and pedagogical insights, possibilities and dilemmas. *International Journal of Early Years Education*, *23*(1), 83-96. doi:10.1080/09669760.2014.976609

Hedges, H. (2019). Working theories, children's curiosity, cognitive development and critical thinking. In M. A. Peters (Ed.), *Encyclopedia of teacher education* (pp. 1-6). Singapore: Springer. doi:10.1007/978-981-13-1179-6_89-1

Hedges, H., & Cooper, M. (2014). Engaging with holistic curriculum outcomes: Deconstructing "working theories". *International Journal of Early Years Education*, *22*(4), 395-408. doi:10.1080/09669760.2014.968531

Hedges, H., & Cooper, M. (2014a). *Inquiring minds, meaningful responses: Children’s interests, inquiries, and working theories*. Wellington, New Zealand: Teaching Learning

Research Initiative. Retrieved from www.tlri.org.nz/tlri-research/research-completed/ece-sector/inquiring-minds-meaningful-responses-children%E2%80%99s.

Hedges, H., & Cooper, M. (2016). Inquiring minds: Theorizing children's interests. *Journal of Curriculum Studies, 48*(3), 303-322. doi:10.1080/00220272.2015.1109711

Hedges, H., & Cullen, J. (2005). Subject knowledge in early childhood curriculum and pedagogy: Beliefs and practices. *Contemporary Issues in Early Childhood, 6*(1), 66-79. doi:10.2304/ciec.2005.6.1.10

Hedges, H., & Cullen, J. (2012). Participatory learning theories: A framework for early childhood pedagogy. *Early Child Development and Care, 182*(7), 921-940. doi:10.1080/03004430.2011.597504

Hedges, H., & Jones, S. (2012). Children's working theories: The neglected sibling of Te Whāriki's learning outcomes. *Early Childhood Folio, 16*(1), 34-39.

Hill, M. (2015). *Dead forever: Young children building theories in a play-based classroom.* (Unpublished doctoral dissertation). Retrieved from www.etheses.whiterose.ac.uk/9379/1/M%20Hill%20Final%20Thesis%20June%202015.pdf

Hodson, D. (2009). *Teaching and learning about science: Language, theories, methods, history, traditions and values*. Boston, MA: Sense.

Hood, N., Kupferman, D. W., Mika, C., Gibbons, A., Craw, J., McPhail, G. Aitken, G., & Murrihy, L. (2018). *On knowledge: Towards understandings of the place(s), space(s), and role(s) of knowledge in and for education.* Auckland, New Zealand: The Education Hub.

John, M. S., Sibuma, B., Wunnava, S., Anggoro, F., & Dubosarsky, M. (2018). An iterative participatory approach to developing an early childhood problem-based STEM curriculum. *European Journal of STEM Education, 3*(3), 1-12. doi:10.20897/ejsteme/3867

Jung, M., & Conderman, G. (2013). Intentional mathematics teaching in early childhood classrooms. *Childhood Education, 89*, 173-177. doi: 10.1080/00094056.2013.792689

Kamberelis, G., Dimitradis, G., & Welker, A. (2018). Focus group research and/in figured worlds. In N. Denzin & Y. Lincoln (Eds.), *The Sage handbook of qualitative research* (5th ed., pp. 692-716). Thousand Oaks, CA: Sage.

Katz, L. G. (2010, Fall). STEM in the early years. Paper presented at the *STEM in Early Education and Development Conference*, University of Northern Iowa, USA. Retrieved from www.ecrp.uiuc.edu/beyond/seed/katz

Kelly, J., White, E. J., Dekker, M., Donald, J., Hart, K., McKay, F., McMillan, L., Mitchell-King, A., & Wright, G. (2013). *The Ngahere project: Teaching and learning possibilities in nature settings*. Hamilton, New Zealand: Wilf Malcolm Institute of Educational Research.

Kelly-Ware, J. (2016). 'What's he doing that for? he's a boy!': Exploring gender and sexualities in an early childhood setting. *Global Studies of Childhood, 6*(1), 147-154. doi:10.1177/2043610615624519

Kelly-Ware, J. P. (2018). *Negotiating fairness and diversity: Stories from an Aotearoa New Zealand kindergarten.* (Doctoral thesis, The University of Waikato, Hamilton, New Zealand). Retrieved from https://hdl.handle.net/10289/12132

Kim, M. (2014). Doing social constructivist research means making empathic and aesthetic connections with participants. *European Early Childhood Education Research Journal, 22*(4), 538-553. doi:10.1080/1350293X.2014.947835

Kinzie, M. B., Whittaker, J. V., McGuire, P., Lee, Y., & Kilday, C. (2015). Research on curricular development for pre-kindergarten mathematics and science. *Teachers College Record, 117*(7), 1-40.

Kozulin, A. (2003). Psychological tools and mediated learning. In A. Kozulin, B. Gindis, V. S. Ageyev, & S. M. Miller (Eds.), *Vygotsky's educational theory in cultural context* (pp. 15-38). Cambridge, UK: Cambridge University Press. doi:10.1017/CBO9780511840975

Kozulin, A. (2018). Mediation and internalization: Conceptual analysis and practical applications. In J. P. Lantolf, M. E. Poehner, & M. Swain (Eds.), *The Routledge handbook of sociocultural theory and second language development* (pp. 23-41). New York, NY: Routledge.

Krieg, S. (2010). The professional knowledge that counts in Australian contemporary early childhood teacher education. *Contemporary Issues in Early Childhood, 11*(2), 144-155. doi:10.2304/ciec.2010.11.2.144

Krieg, S. (2011). The Australian early years learning framework: Learning what? *Contemporary Issues in Early Childhood, 12*(1), 46-55. doi:10.2304/ciec.2011.12.1.46

Kumtepe, A. T., & Genc-Kumtepe, E. (2015). STEM in early childhood education: We talk the talk, but do we walk the walk? In Information Resources Management Association (Ed.), *STEM education: Concepts, methodologies, tools, and applications* (pp. 1-24). Hershey, PA: IGI Global. doi:10.4018/978-1-4666-7363-2.ch001

Lea, D., & Bradberry, J. (2020). *Oxford advanced learner's dictionary.* (10th ed.). Oxford: Oxford University Press. Retrieved from http://www.oxfordlearnersdictionaries.com

Lee, W., Carr, M., & Soutar, B. (2013). *Understanding the Te Whāriki approach: Early years education in practice*. New York, NY: Routledge.

Lindeman, K. W., Jabot, M., & Berkley, M. T. (2013). The role of STEM (or STEAM) in the early childhood setting. In L. E. Cohen & S. Waite-Stupiansky (Eds.), *Learning across the early childhood curriculum* (pp. 95-114). Greenwich, CT: Emerald Insight. doi:10.1108/S0270-4021(2013)0000017009

Linder, S., Powers-Costello, B., & Stegelin, D. (2011). Mathematics in early childhood: Research-based rationale and practical strategies. *Early Childhood Education Journal, 39*(1), 29-37. doi:10.1007/s10643-010-0437-6

Lippard, C., Lamm, M., Tank, K., & Choi, J. (2019). Pre-engineering thinking and the engineering habits of mind in preschool classroom. *Early Childhood Education Journal, 47*(2), 187-198. doi:10.1007/s10643-018-0898-6

Lovatt, D. (2013). *Children's working theories: Provoking disequilibrium* (Unpublished master's thesis). University of Auckland: Auckland, New Zealand.

Lovatt, D. (2014). How might teachers enrich children's working theories? Getting to the heart of the matter. *Early Childhood Folio, 18*(1), 28-34.

Lovatt, D., & Hedges, H. (2014). The construct of working theories: Constructivist and sociocultural perspectives. In H. Hedges & V. Podmore (Eds.), *Early Childhood Education: Pedagogy, Professionalism, and Policy* (pp. 29-42). Auckland, New Zealand: Edify.

Lovatt, D., & Hedges, H. (2015). Children's working theories: Invoking disequilibrium. *Early Child Development and Care, 185*(6), 909-925. doi:10.1080/03004430.2014.967688

MacDonald, A. (2013). Using children's representations to investigate meaning-making in mathematics. *Australasian Journal of Early Childhood, 38*(2), 65-73.

MacDonald, A., & Rafferty, J. (2015). *Investigating mathematics, science and technology in early childhood*. Melbourne, Australia: Oxford University Press.

Magrini, J. (2010). How the conception of knowledge influences our educational practices: Toward a philosophical understanding of epistemology in education. *Curriculum Matters, 6*, 6-27.

Marginson, S., Tytler, R., Freeman, B., & Roberts, K. (2013). *STEM: Country comparisons: International comparisons of science, technology, engineering and mathematics (STEM) education. Final report.* Melbourne, Australia: Australian Council of Learned Academies.

Mawson, B. (2003). Smoothing the path: Technology education and school transition. *Research in Science Education, 33*(4), 503-514.

Mawson, B. (2007). Designers as teachers and learners: Transferring workplace design practice into educational settings. *International Journal of Technology and Design Education, 17*(2), 163-177. doi:10.1007/s10798-006-0002-1

Mawson, B. (2011). Technological funds of knowledge in children's play: Implications for early childhood educators. *Australasian Journal of Early Childhood, 36*(1), 30-35.

Mawson, B. (2013). Emergent technological literacy: What do children bring to school? *International Journal of Technology and Design Education, 23*(2), 443-453. doi:10.1007/s10798-011-9188-y

Maxwell, J. (2013). *Qualitative research design: An interactive approach* (3rd ed.). Thousand Oaks, CA: Sage.

McChesney, J. (2017). Mathematics in early childhood: Nourishing and nurturing Te Kākano. *Early Childhood Folio, 21*(2), 3-7. doi:10.18296/ecf.0038

McClure, E., Guernsey, L., Clements, D. H., Bales, S. N., Nichols, J., Kendall-Taylor, N., & Levine, M. H. (2017). *STEM starts early: Grounding science, technology, engineering, and math education in early childhood*. New York, NY: The Joan Ganz Cooney Center at Sesame Workshop.

Mead, H.M. & Grove, N. (2001). *Ngā pepeha a ngā Tipuna*. Wellington, New Zealand: Victoria University Press.

Meade, A., & Cubey, P. (2008). *Thinking children: Learning about schemas* (2nd ed.). Wellington, New Zealand: New Zealand Council for Educational Research.

Merriam, S. B., & Tisdell, E. J. (2016). *Qualitative research: A guide to design and implementation* (4th ed.). San Francisco, CA: Jossey-Bass.

Miles, M. B., Huberman, A. M., & Saldaña, J. (2014). *Qualitative data analysis: A methods sourcebook* (3rd ed.). Thousand Oaks, CA: Sage.

Ministry of Business, Innovation and Employment. (2014). *Occupation outlook 2014*. Wellington, New Zealand: New Zealand Government.

Ministry of Education. (1993). *Te Whāriki: He whāriki mātauranga mō ngā mokopuna o Aotearoa: Draft guidelines for developmentally appropriate programmes in early childhood services*. Wellington, New Zealand: Learning Media.

Ministry of Education. (1996). *Te Whāriki: He whāriki matauranga mō ngā mokopuna o Aotearoa: Early childhood curriculum*. Wellington, New Zealand: Learning Media.

Ministry of Education. (1998). *Quality in action. Te mahi whai hua: Implementing the revised statement of desirable objectives and practices in New Zealand early childhood services*. Wellington, New Zealand: Learning Media.

Ministry of Education. (2009). *Kei tua o te pae. Assessment for learning: Early childhood exemplars*. Wellington, New Zealand: Learning Media.

Ministry of Education. (2010). *Te aho tukutuku: Early mathematics [CD rom]*. Wellington, New Zealand: Ministry of Education.

Ministry of Education. (2017). *Te Whāriki: He whāriki mātauranga mō ngā mokopuna o Aotearoa: Early childhood curriculum*. Wellington, New Zealand: Ministry of Education.

Ministry of Education. (2018). *ECE funding handbook*. Wellington, New Zealand: Ministry of Education.

Moomaw, S. (2013). *Teaching STEM in the early years: Activities for integrating science, technology, engineering, and mathematics*. St. Paul, MN: Redleaf Press.

National Science and Technology Council. (2013). *Federal science, technology, engineering and mathematics (STEM) education 5-year strategic plan: A report from the committee on STEM education*. Washington, DC: Executive Office of the President.

New Zealand Government. (2018). *Education (early childhood services) regulations 2008 (reprinted 2018)*. Wellington, New Zealand: New Zealand Government.

Nuttall, J. (2005). Looking back, looking forward: Three decades of early childhood curriculum development in Aotearoa New Zealand. *Curriculum Matters, 1*, 12-28.

Organisation for Economic Co-operation and Development. (2012). *Starting strong III: A quality toolbox for early childhood education and care.* Paris, France: OECD. doi:10.1787/9789264123564-en

Paavola, S., Engeström, R., & Hakkarainen, K. (2012). The trialogical approach as a new form of mediation. In A. Moen, A. I. Morch, & S. Paavola (Eds.), *Collaborative knowledge creation: Practices, tools, concepts*. Dordrecht, Netherlands: Springer.

Park, M., Dimitrov, D. M., Patterson, L. G., & Park, D. (2017). Early childhood teachers' beliefs about readiness for teaching science, technology, engineering, and mathematics. *Journal of Early Childhood Research, 15*(3), 275-291. doi:10.1177/1476718X15614040

Peters, S., & Davis, K. (2011). Fostering children's working theories: Pedagogic issues and dilemmas in New Zealand. *Early Years: An International Journal of Research and Development, 31*(1), 5-17. doi:10.1080/09575146.2010.549107

Peters, S., & Davis, K. (2015). Babies, boys, boats and beyond: Children's working theories in the early years. In S. Robson & S. Flannery-Quinn (Eds.), *The Routledge international handbook of young children's thinking and understanding* (pp. 251-261). Abingdon, UK: Routledge.

Peters, S., Davis, K., & McKenzie, R. (2018). Children's 'working theories' as curriculum outcomes. In C. Trevarthen, J. Delafield-Butt, & A. Dunlop (Eds.), *The child's curriculum: Working with the natural values of young children* (1st ed., pp. 296-308). Oxford, UK: Oxford University Press. doi:10.1093/oso/9780198747109.003.0016

Piaget, J. (1970). *Science of education and psychology of the child*. New York, NY: Oxford University Press.

Pinar, W. F. (2012). *What is curriculum theory?* (2nd ed.). New York, NY: Routledge

Podmore, V., Hedges, H., Keegan, P.J., & Harvey, N. (2015). *Children who learn in more than one language: Early childhood teachers afloat in plurilingual seas*. Wellington, New Zealand: Teaching Learning Research Initiative. Retrieved from www.tlri.org.nz/sites/default/files/projects/TLRI_Podmore_Final%20report%20-%20web%20ready_1.pdf

Preissle, J., & LeCompte, M. (1984). *Ethnography and qualitative design in educational research*. Orlando, Fl: Academic Press.

Ravitch, S. M., & Riggan, M. (2012). In M. Riggan (Ed.), *Reason & rigor: How conceptual frameworks guide research*. Thousand Oaks, CA: Sage.

Ritchie, J. (2018). A fantastical journey: Reimagining Te Whāriki. *Early Childhood Folio, 22*(1), 9-14. doi:10.18296/ecf.0046

Ritchie, J., & Skerrett, M. (2014). *Early childhood education in Aotearoa New Zealand: History, pedagogy, and liberation*. New York, NY: Palgrave MacMillan.

Robson, S. (2011). Producing and using video data in the early years: Ethical questions and practical consequences in research with young children. *Children & Society, 25*(3), 179-189. doi:10.1111/j.1099-0860.2009.00267.x

Robson, S., & Flannery-Quinn, S. (Eds.). (2015). *The Routledge international handbook of young children's thinking and understanding*. Abingdon, UK: Routledge.

Rogoff, B. (1998). Cognition as a collaborative process. In W. Damon (Ed.), *Handbook of child psychology: Volume 2. Cognition, perception and language* (pp. 679-744). New York, NY. John Wiley & Sons.

Roth, W., & Eijck, M. V. (2010). Fullness of life as minimal unit: Science, technology, engineering, and mathematics (STEM) learning across the life span. *Science Education, 94*(6), 1027-1048. doi:10.1002/sce.20401

Ryan, S., & Lobman, C. (2007). The potential of focus groups to inform early childhood policy and practice. In J. A. Hatch (Ed.), *Early childhood qualitative research* (pp. 63-74). New York, NY: Routledge.

Sands, L., Carr, M., & Lee, W. (2012). Question-asking and question-exploring. *European Early Childhood Education Research Journal, 20*(4), 553-564. doi:10.1080/1350293X.2012.737705

Saracho, O. N., & Spodek, B. (2008). Scientific and technological literacy research: Principles and practices. In O. N. Saracho & B. Spodek (Eds.), *Contemporary perspectives on science and technology in early childhood education* (pp. 1-16). Charlotte, NC: Information Age.

Saracho, O. N., & Spodek, B. (2008a). A future research agenda for early childhood science and technology. In O. N. Saracho & B. Spodek (Eds.), *Contemporary perspectives on science and technology in early childhood education* (pp. 167-181). Charlotte, NC: Information Age.

Scardamalia, M., & Bereiter, C. (2003). Knowledge building. In J.W. Guthrie (Ed.), *Encyclopedia of education* (2nd ed., pp. 1370-1373). New York, NY: Gale, Cengage Learning.

Scardamalia, M., & Bereiter, C. (2006). Knowledge building: Theory, pedagogy and technology. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (pp. 97-115). Cambridge, UK: Cambridge University Press.

Schaffer, H. (1992). Joint involvement episodes as context for development. In H. McGurk (Ed.), *Childhood social development: Contemporary perspectives* (pp. 99-130). Hove, UK: Lawrence Erlbaum.

Shenton, A. K. (2004). Strategies for ensuring trustworthiness in qualitative research projects. *Education for Information, 22*, 63-75. doi:10.3233/EFI-2004-22201

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review, 57*, 1-22. doi:10.17763/haer.57.1.j463w79r56455411

Shulman, L. S., & Grosman, P. L. (1998). *Knowledge growth in teaching: A final report to the Spencer Foundation*. Stanford, CA: Stanford University Press.

Simmons, H., Schimanski, L., McGarva, P., Cullen, J., & Haworth, P. (2005). Teachers researching young children's working theories. *Early Childhood Folio, 9*, 18-22.

Simoncini, K., & Lasen, M. (2018). Ideas about STEM among Australian early childhood professionals: How important is STEM in early childhood education? *International Journal of Early Childhood: Journal of OMEP: L'Organisation Mondiale Pour L'Education Prescolaire, 50*(3), 353-369. doi:10.1007/s13158-018-0229-5

Simons, H. (2009). *Case study research in practice*. London, UK: Sage.

Siraj-Blatchford, I. (2007). Creativity, communication and collaboration: The identification of pedagogic progression in sustained shared thinking. *Asia-Pacific Journal of Research in Early Childhood Education, 1*(2), 3-23.

Siraj-Blatchford, I. (2009). Conceptualising progression in the pedagogy of play and sustained shared thinking in early childhood education: A Vygotskian perspective. *Education and Child Psychology, 26*(2), 77-89.

Siraj-Blatchford, I., Sylva, K., Muttock, S., Gilden, R., & Bell, D. (2002). *Researching effective pedagogy in the early years*. London, UK: Dept. for Education and Skills, University of Oxford.

Siry, C., & Max, C. (2013). The collective construction of a science unit: Framing curricula as emergent from kindergarteners' wonderings. *Science Education, 97*(6), 878-902. doi:10.1002/sce.21076

Smith, A. (2013). *Understanding children and childhood: A New Zealand perspective* (5th ed.). Wellington, New Zealand: Bridget Williams Books.

Stake, R. (1995). *The art of case study research*. Thousand Oaks, CA: Sage.

Stelmach, B. (2016). Issues with evidence in constructivist/interpretivist educational research. In P. Newton, & D. Burgess (Eds.), *The best available evidence: Decision making for educational improvement* (pp. 19-32). Rotterdam, Netherlands: Sense.

Stubbs, K., & Yanco, H. (2009). STREAM: A workshop on the use of robotics in K-12 STEM education. *IEEE Robotics & Automation Magazine 16*(4), 17-19. doi:10.1109/MRA.2009.934830

Sylva, K., & Roberts, K. (2010). Quality in early childhood for early childhood education and care: Evidence for long term effects. In G. Pugh & B. Duffy (Eds.), *Contemporary issues in the early years* (5th ed., pp. 47-62). London, UK: Sage.

Tippett, C. D., & Milford, T. M. (2017). Findings from a pre-kindergarten classroom: Making the case for STEM in early childhood education. *International Journal of Science and Mathematics Education, 15*(1), 67-86. doi:10.1007/s10763-017-9812-8

Tracy, S. J. (2010). Qualitative quality: Eight “big-tent” criteria for excellent qualitative research. *Qualitative Inquiry, 16*(10), 837-851. doi:10.1177/1077800410383121

Tyler-Merrick, G., Phillips, J., McLachlan, C., Aspden, T., & Cherrington, S. (2018). Early childhood education and care in Aotearoa/New Zealand. In S. Garvis, S. Phillipson, & H. Harju-Luukkainen (Eds.), *International perspectives on early childhood education and care: Early childhood education in the 21st century, volume 1* (pp. 127-142). London, UK: Routledge.

Uğraş, M., & Genç, Z. (2018). Investigating preschool teacher candidates' STEM teaching intention and the views about STEM education. *Bartin Üniversitesi Egitim Fakültesi Dergisi, 7*(2), 724-744. doi:10.14686/buefad.408150

van Meeteren, B., & Zan, B. (2010, Fall). Revealing the work of young engineers in early childhood education. Paper presented at the *STEM in Early Education and Development Conference*, University of Northern Iowa, USA. Retrieved from www.ecrp.illinois.edu/beyond/seed/zan.html

Vygotsky, L. (1966). Play and its role in the mental development of the child. *Voprosy Psikhologii, 12*(6), 62-76.

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Vygotsky, L.S. (1986). *Thought and language*. Cambridge, MA: MIT Press.

Vygotsky, L. S. (1998). *The collected works of L.S. Vygotsky. Volume 5: Child psychology*. New York, NY: Plenum Press.

Walsh, D. J., Bakir, N., Lee, T. B., Chung, Y., & Chung, K. (2007). Using digital video in field-based research with children: A primer. In J. A. Hatch (Ed.), *Early childhood qualitative research* (pp. 43-62). New York, NY: Routledge.

Wartofsky, M. (1979). *Models, representation and scientific understanding*. Boston, MA: Reidel.

Wells, G. (1999). *Dialogic inquiry: Towards a sociocultural practice and theory of education*. New York, NY: Cambridge University Press.

Wells, G. (2000). Dialogic inquiry in education: Building on the legacy of Vygotsky. In C. D. Lee & P. Smagorinsky (Eds.), *Vygotskian perspectives on literacy research: Constructing meaning through collaborative inquiry* (pp. 51-85). Cambridge, UK: Cambridge University Press.

Wells, G. (2002). Learning and teaching for understanding: The key role of collaborative knowledge building. *Advances in Research on Teaching, 9*, 1-42.

Wells, G. (2008). Dialogue, inquiry and the construction of learning communities. In B. Lingard, J. Nixon, & S. Ranson (Eds.), *Transforming learning in schools and communities: The remaking of education for a cosmopolitan society* (pp. 236-256). New York, NY: Continuum.

Wertsch, J. V. (1991). *Voices of the mind: A sociocultural approach to mediated action*. Cambridge, MA: Harvard University Press.

Wertsch, J. (1995). Action in sociocultural research. In J. Wertsch, P. Del Rio, & A. Alvarez (Eds.), *Sociocultural studies of mind* (pp. 56-74). New York, NY: Cambridge University Press. doi:10.1017/CBO9781139174299

Wertsch, J. V. (2007). Mediation. In H. Daniels, M. Cole, & J. V. Wertsch (Eds.), *The Cambridge companion to Vygotsky* (pp. 178-192). Cambridge, MA: Cambridge University Press. doi:10.1017/CCOL0521831040.008

White, J., Ellis, F., O'Malley, A., Rockel, J., Stover, S., & Toso, M. (2009). Play and learning in Aotearoa New Zealand early childhood education. In I. Pramling-Samuelsson & M. Fleer (Eds.), *Play and learning in early childhood settings* (pp. 19-49). Rotterdam, Netherlands: Springer. doi:10.1007/978-1-4020-8498-0_2

White, H. (2011). Constructivism. In J. Newman (Ed.), *Green education: An A-Z* guide (pp. 90-92). Thousand Oaks, CA: Sage. doi:10.4135/9781412974615.n27

Williamson, J., Lovatt, D., & Hedges, H. (2020). Looking beyond books and blocks: Peers playing around with concepts. In A. Ridgway, G. Quinones, & L. Li (Eds.), *Peer play and relationships in early childhood: International research perspectives* (pp 194-211). Switzerland: Springer.

Wood, E., & Hedges, H. (2016). Curriculum in early childhood education: Critical questions about content, coherence, and control. *The Curriculum Journal*, *27*(3), 387-405. doi:10.1080/09585176.2015.1129981

Wylie, C., Hogden, E., Ferral, H., & Thompson, J. (2006). *Contributions of early childhood education to age-14 performance: Evidence from the longitudinal competent children, competent learners study*. Wellington, New Zealand: New Zealand Council for Educational Research.

Yin, R. (2014). *Case study research* (5th ed.). Thousand Oaks, CA: Sage.

Yin, R. K. (2015). *Qualitative research from start to finish* (2nd ed.). New York, NY: Guilford Publications.

Yin, R. (2018). *Case study research and applications: Design and methods*. Thousand Oaks, CA: Sage.

Zucker, T. A., Williams, J. M., Bell, E. R., Assel, M. A., Landry, S. H., Monsegue-Bailey, P., Crawford, A., & Bhavsar, V. (2016). Validation of a brief, screening measure of low-income pre-kindergarteners' science and engineering knowledge. *Early Childhood Research Quarterly*, *36*, 345-357. doi:10.1016/j.ecresq.2015.12.018