School of Education

Exploring STEM with a focus on engineering and creativity in an early childhood setting

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Declaration

To the best of my knowledge and belief, this thesis contains no material previously published by any other person except where due acknowledgment has been made.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

The research presented and reported in this thesis was conducted in accordance with the National Health and Medical Research Council National Statement on Ethical Conduct in Human Research (2007) – updated March 2014. The proposed research study received human research ethics approval from the Curtin University Human Research Ethics Committee (EC00262), Approval Number HRE2019-0089

Signature: ………………………………………….

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Abstract

The integration of Science, Technology, Engineering and Mathematics (STEM) is a major national agenda in education and there has been growing recognition of the need to establish STEM competencies and dispositions in early childhood settings. Not only is there a demand for individuals in STEM related occupations, it is important to equip young people with the skills and dispositions to help with the current and future world challenges (Blackley & Howell, 2015). However, society is experiencing issues in STEM fields including a reported lack of interest in STEM subjects among adolescents and the decline in creativity of young children (Chapman & Vivian, 2016). In early childhood education, theories of social constructivism and constructionism create a foundation for engineering design processes and arguably increased creativity development. This study set out to investigate the effect of the STEM engineering design process on young children's creativity. Through action research, I observed young children aged three and four years old in an early childhood setting, engaging in their everyday play. An engineering design process was then implemented in two action cycles and as a result the children demonstrated an increase in engagement and characteristics of creativity including trial and error, collaboration, using objects in ways other than their intended use, asking questions, and reflection and evaluation. In addition, overarching social and emotional capabilities such as resilience and perseverance were enhanced. The children who participated in the study were found to be more engaged once the engineering design process was implemented, increasing the time spent on their creations. Through this study, I was able to reflect critically on my pedagogy and practice as an early childhood educator working with young children to enhance STEM learning, specifically the engineering design process and creativity. The study demonstrates strategies to other early childhood educators, for incorporating STEM engineering in their learning settings and how to monitor children's creativity. Not only does this study have the potential to inform early childhood educators, it can also inform pre-service educators and educator training institutions in developing their pedagogical practices around STEM and creativity in young children.

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Chapter 1. Introduction

1.1 Overview

I am an early childhood educator who has been working in the early years sector for 12 years. For the past eight years I have been working at an early childhood centre situated on a university campus in Perth, Western Australia. My role at the centre began as an Early Childhood Educator, before I moved into a Team Leader position in one of the kindergarten rooms for children aged three to five years old. Since starting this study, I have taken on the role of Education Support, offering pedagogical leadership to the educators at the centre and a Co-ordinator position where I take on a leadership role around the everyday operation of the centre. Prior to beginning this study, I was involved in research focused on digital technologies in STEM and their use with young children in the early years, exploring tangible coding devices and how they can develop children's STEM dispositions (Murcia et al., 2020b). Through this study, I was drawn to the engineering design process and wanted to further my pedagogical knowledge around this topic. I was also attracted to the notion of creativity in early childhood as I believe this is a vital component of young children's development and that young children should be supported in their creative endeavours.

1.2 Background

The term STEM is the integration of two or more subjects of science, technology, engineering and mathematics (Kelley & Knowles, 2016). In 2001, the acronym was employed by Judith Ramaley, then assistant director of the Education and Human Resources Directorate at the National Science Foundation (NSF) in the United States of America (USA) (Chute, 2009). The previous acronym, SMET, was changed to STEM by Dr Ramaley as she believed that science and mathematics were not better or ahead of technology and engineering, but rather, support them (Chute, 2009). STEM is a major national agenda in Australian education and there has been growing recognition of the importance of early childhood education to establish STEM competencies and dispositions. For example, the National STEM School Education Strategy 2016-2026 was agreed on by all Australia's state education ministers in 2015 to encourage students to take up STEM subjects to meet the demand of STEM related careers (Australian Government Department of Education Skills and Employment, 2022).

Not only is there a demand for individuals in STEM related occupations, there is also a need to help with the current and future world challenges (Blackley & Howell, 2015).

However, Australia is experiencing issues in STEM fields including a lack of interest in STEM subjects among adolescents and a reported decline in creativity among young children (Chapman & Vivian, 2016). The Australian Government has put in place some initiatives for early years learning to develop foundational STEM competencies and dispositions that children can carry on into their adolescence and adult lives. Programs including *Early Learning STEM Australia* (ELSA), *Let's Count*, *Little Scientists* and Early Learning STEM Research Apps (Australian Government Department of Education Skills and Employment, 2022). These initiatives not only assist young children in their STEM learning but also educators and parents in how to foster and deliver STEM learning experiences for young children (Australian Government Department of Education Skills and Employment, 2022).

In support of increased emphasis on STEM, the world has been facing issues such as incurable illnesses and there is a recognised need to create more sustainable lifestyles due to the changes in the natural environment (Chapman & Vivian, 2016; Marrero et al., 2014). According to Thomas and Watters (2015), "Global problems such as climate change, overpopulation, resource management, agricultural production, health, biodiversity, declining energy and water sources among other issues put even more pressure on developing science and technology and require an international approach to resolving these issues" (p. 42). Van Meeteren and Zan (2010) report that the increased emphasis on STEM in the curriculum can assist in maintaining quality of life and advancing the ever-changing world.

By introducing STEM concepts into early childhood education, dispositions for learning in this area are more likely to be carried on into adolescence and young adulthood and hopefully more individuals will be inclined to pursue STEM related careers. According to Sternberg (2007), there has been an alarming decline in young children's creativity as there is a need for creative people inventing and discovering to create a better world. Creativity should be fostered from early childhood through to adolescence in order for individuals to develop into creative adults. STEM learning and creativity correspond with one another and through the integrated nature of STEM, including the engineering design process, characteristics of creativity can be enhanced (Pantoya et al., 2015).

1.3 Statement of Research

Research demonstrates there is a decline of interest in STEM subjects among adolescents and this is evident from early childhood. Therefore, there is a need to encourage more STEM engagement in the early childhood years, particularly in relation to the development of creative capacity within young children to engage effectively with STEM concepts.

1.4 Research Aims and Objectives

This study set out to explore the potential for children's creative engagement with STEM using an engineering design process. I set out to investigate how children use engineering in their free play whilst observing their creativity. Then, through the introduction of an inquiry questioning design process, I explored how children engaged with two planned STEM engineering activities. Lastly, I investigated the effects of the inclusion of the inquiry questioning design process on children's creativity. In order to achieve the research aim, this study was guided by the following research question:

> *How do young children respond to the intentional inclusion of an engineering design process in early childhood integrated STEM activities?*

The study was further guided by three sub-questions:

- *How can an engineering design process be adapted and implemented in young children's play (three and four years old)?*
- *How can young children's development of creativity be monitored?*
- *How does the design process effect young children's demonstration of creativity?*

1.5 Research Overview

Social Constructivism and Constructionism

This study is informed by social constructivism and constructionism. The theory of social constructivism states that knowledge is constructed through lived experiences, and through interaction with others (Pritchard & Woollard, 2010). Constructionism is similar to social constructivism in that knowledge is constructed by the individual, but also involves the creation of a tangible object to gain knowledge (Papert, 1993). Early childhood theories of social constructivism and constructionism create a foundation for the introduction of the engineering design process in the early childhood years and aid in creativity development. For the purpose of this study, the engineering design process is based on Murcia et al. (2020a) Inquiry Questioning Model which includes seven stages: Asking, Imagining, Creating, Trying out, Improving, Reflecting, and Reasoning.

Action Research

In order to achieve the research aim, I chose an action research approach as this fits my role as a practitioner researcher. I would be able to implement ideas and approaches, evaluate them and reframe them as part of an ongoing cycle of research. Accordingly, this study involved three action research cycles (Creswell, 2008).

Cycle One

Cycle one involved observing the children's creativity whilst engaging in activities available in the everyday environment, taking photographs to document their learning and writing down the dialogue. To do this I created an indicators of creativity checklist using literature from Guilford (1950), Torrance (1977), Sternberg (2007) and Murcia et al. (2020b). I also modified, a learning story template, an assessment tool used by the early childhood centre, to suit the study (Knauf, 2020). From this cycle, the choice was made to create boats in cycle two. Prior to commencing cycle two, I used the Inquiry Questioning Model (Murcia et al., 2020a) to plan the resources, mathematical language to be used and open-ended questions at each stage of the engineering design process. After each session, I wrote a learning story outlining what occurred, including dialogue and supporting photographs, an analysis of the learning, and my personal reflections of what occurred and what to do next. Using the analysed learning stories, I was then able to complete the indicators of creativity checklist.

Cycle Two

In cycle two, I implemented the engineering design process with the children, introducing the problem of how to get Sally the doll across a water trough. The children created boats, testing them out and refining their designs until they were successful. Audio of dialogue was recorded, and photographs taken to document the learning. Two children collaborated and completed the task in two sessions. Another two children succeeded in four sessions and two children individually completed the task in one session each. Therefore, a total of eight sessions were conducted for cycle two. I began writing the learning stories for cycle two, however due to time constraints, had to continue on with cycle three, planning for the sessions using the Inquiry Questioning Model developed by Murcia et al. (2020a) before implementing it with the children.

Cycle Three

Throughout cycle two I reflected on my practice and for cycle three I wanted to be more explicit with my language and open-ended questioning with the children. Cycle three involved the children creating a bridge for the Three Billy Goats Gruff which they were able to achieve in two sessions, one session with three children collaborating together and the other with two children. After the completion of cycle three, I continued to write the learning stories, listening to the audio and analysing the learning from cycles two and three. After finishing each learning story, I used the analysed data to complete the indicators of creativity checklist.

Write Up of Findings

Once I had finished writing the learning stories, using the completed indicators of creativity checklist, I generated a frequency table for each child. I then documented in a table how long it took for each child to complete the sessions within each of the cycles. After this, I was able to note any obvious characteristics of creativity. Once I had completed this for all the children in the study, I created a cross case comparison of the indicators of creativity, observing any consistencies in the data for each stage of the design process and in the overarching social and emotional capabilities. The research timeline is presented below in table 1.1.

Table 1.1 Timeline of research

Date	Procedure
December, 2018	Creation of data collection tools
May, 2019	Commenced data collection
May, 2019	Commenced data analysis, writing of learning stories and indicators of creativity checklist
December, 2019	Conclusion of data collection
August, 2021	Completed data analysis, writing of learning stories and indicators of creativity checklist
August, 2021	Frequency of indicators for each child and across cases
September, 2021	Write up of findings commenced

1.6 Organisation of the Thesis

Chapter 1 introduces the context of the study, including the study aims, research questions and method of inquiry. Chapter 2 presents a detailed literature review into the theoretical perspectives surrounding the study, including social constructivism and constructionism, as well as background information around STEM and the engineering design process, creativity, play-based learning, inquiry-based learning, the cycle of planning, the purpose of learning stories and critical reflection. It also includes the conceptual framework for the study. Chapter 3 presents the paradigm and epistemological stance of the study, as well as the methodology used, a case study design through action research by a practitioner researcher. It also includes a summary indicating the means of data collection and analysis. In chapter 4, the findings of the study are explored, looking at each child as a case, then analysing the findings across the six cases while chapter 5 discusses the research questions in relation to the findings and the literature review. It concludes with recommendations for future practice drawn from the study. Chapter 6 concludes the thesis by reiterating the aim and significance of the study in relation to the problem statement. It then presents the limitations of the study, recommendations for future research and the concluding remarks.

1.7 Significance of the Study

Early childhood education promotes learning through hands-on experiences, discovery, play and collaboration in a holistic manner, and these dispositions align with STEM teaching and learning as well as developing children's creativity (Linder et al., 2016; Tickle, 1996). It is important to encourage young people into STEM fields as a variety of people with different ideas, perspectives and values are needed to combat the problems that the world faces today and may face into the future. As there is limited literature around STEM engineering in early childhood, this study is valuable as it adds to the growing body of knowledge surrounding STEM education, the engineering design process and creativity in early childhood. This study provides information and inspiration to other educators by offering strategies for incorporating STEM engineering into their curriculum and fostering young children's creativity. Not only does this study have the potential to inform early childhood educators on how to incorporate STEM engineering in their early years settings, it can also assist pre-service educators and educator training institutes in developing their pedagogical practices around STEM and creativity in young children.

1.8 Summary

This chapter has set out the background context, research problem, research objectives, an overview of the research, how the thesis is organised and the significance of the study. I am passionate about early childhood education and began this study with an interest in developing my STEM engineering and creativity pedagogy and practice. Through early exposure to STEM education with a focus on building creative capacity, young children can develop foundational skills and dispositions that can be further extended into their adolescence and adulthood. This will assist in the reported declines of interest in STEM as it is vital that the next generation is equipped with twenty-first century skills to combat issues the world is facing today and those that will be faced in the future.

Chapter 2. Literature review

2.1 Introduction

The previous chapter presented an overview of the thesis, including the background context which frames the study, the problem statement, research aims and objectives, an overview of the study, how this thesis is organised and the significance of the study. This chapter now presents a detailed review of the literature relevant to the study.

The chapter commences with an overview of social constructivism and constructionism before discussing STEM in early childhood, more specifically the engineering design process, and creativity in early childhood. It then investigates theories of early childhood education including play-based and inquiry-based learning, before discussing planning and assessment processes such as the cycle of planning, learning stories, and critical reflection as a means for informing practice. Finally, the chapter concludes with the conceptual framework for the study and a summary of the chapter.

2.2 From Social Constructivism to Constructionism

Social constructivism is a learning theory which states that young children learn about their world and develop cognitive skills through experience, with social interaction being paramount in achieving this (Pritchard & Woollard, 2010). Constructivists place value on the social aspect of learning but regard the individual as the centre of learning. Social constructivists, on the other hand, place an emphasis on social interaction and believe it is imperative for learning (Krause et al., 2010). A social constructivist sees young children as capable learners with language, self-reflection and context supporting their learning (Pritchard & Woollard, 2010). Lev Vygotsky, a social constructivist, developed a social cognitive concept called the *Zone of Proximal Development*. The *Zone of Proximal Development* is the area between what a child already knows and the potential of learning that can occur (Lindon, 2012). Vygotsky believed that a child can broaden their knowledge of specific topics with the assistance of someone who has more of an understanding such as an educator or peer (Pritchard & Woollard, 2010). Vygotsky stressed that children at different levels of knowledge, working in collaboration allows for significant learning. He believed in learning through play as long as it is supported by an educator or a peer with more knowledge (Lindon, 2012).

Seymour Papert, inspired by the works of Jean Piaget, a pioneer in the theory of constructivism, introduced the notion of constructionism. Constructionism uses the same theoretical approach as constructivism but involves children constructing tangible objects in order to gain knowledge (Papert, 1993). Papert believed that learning occurs when children engage in activities that are drawn from their interests and stressed that in a changing world, computers and technology are vital for learning (Branscombe et al., 2014). He encouraged long-term projects where children's thinking is independent but includes time for times of social interaction (Papert, 1993). Children would also be able to comprehend, explain and teach concepts of their creations, therefore developing a deeper understanding of the knowledge behind their creation (Branscombe et al., 2014). The role of the educator in constructionism is to ask questions, provide support, and engage children in authentic tasks to develop knowledge and understanding, and help children document their learning (Branscombe et al., 2014). Papert and his team at the Massachusetts Institute of Technology (MIT) Epistemology and Learning Group believed in the value of constructionism to reform society and his legacy has been continued after his death. The Lifelong Kindergarten Group at MIT aims to create "a world of playfully creative people, who are constantly inventing new possibilities for themselves and their communities," (Branscombe et al., 2014, p. 297).

2.3 STEM in Early Childhood Education

What is STEM?

As outlined in chapter 1, STEM comprises Science, Technology, Engineering and Mathematics. It is now understood that the inclusion of STEM in early childhood education is of great importance and has become a priority of both Australian State and National governments (Simoncini & Lason, 2018). The inclusion of STEM in education has evolved from teaching the individual domains separately, to the integration of these subjects (Kennedy & Odell, 2014). By integrating the STEM learning areas, young children's knowledge can be extended further than teaching these subjects alone. Kelley and Knowles (2016) define integrated STEM education as "the approach to teaching the STEM content of two or more STEM domains, bound by STEM practices within an authentic context for the purpose of connecting these subjects to enhance student learning" (p. 3).

Issues in STEM education and the Field

According to Kelley and Knowles (2016), there has been a decline in the interest of STEM related topics in adolescents and young adults, while Pantoya et al. (2015) report that even by the fourth grade, children show a lack of interest in STEM education. Many researchers report this decline in interest in STEM subjects to be predominant in western countries (Kelley & Knowles, 2016). Kelley and Knowles (2016) state there has been a push for the improvement of STEM education due to shortages in STEM related fields, which is predicted to continue into the future. Pantoya et al. (2015) highlight the importance of early STEM experiences as research suggests student's academic identity can impact future learning. Chubb (in Campbell et al., 2018), states that in the next five to ten years, 75% of the fastest growing occupations will require STEM related skills and experiences. Murphy et al. (2019) state that "STEM education builds intra-disciplinary skills, such as complex problem solving, critical thinking and creativity," (p. 123). These skills, otherwise known as twenty-first century skills, are imperative for our ever-changing world. Richard Riley (in Trilling & Fadel, 2009) stated, "We are currently preparing students for jobs that don't yet exist… using technologies that haven't yet been invented… in order to solve problems we don't even know are problems yet," (p. 3). In Australia, students have little desire to study STEM subjects and those students who choose to study STEM subjects are underperforming in testing compared to other nations (Murphy et al., 2019). By incorporating STEM education in early childhood, educators can potentially influence children's STEM capabilities and dispositions not only through the activities they provide, but also through their pedagogy and practice (MacDonald et al., 2020).

Australian National STEM Agendas

There has been an emergence of studies around STEM education in Australia during the past decade and these studies have highlighted the urgency of delivering quality STEM education to young children. The '*National STEM School Education Strategy 2016–2026'* was put in place to combat issues such as the lack of interest in STEM and to increase STEM capabilities in students. Each Australian state has since released their own strategies for improving issues around STEM through education. Murphy et al. (2019) compared the strategies put in place by Australian state governments regarding STEM education and reported that while there was emphasis placed on building student's STEM capabilities and educator's capacity to deliver STEM programs, not all concerns within STEM literature had been addressed, and under half of the states mentioned early childhood education and the importance of STEM education in the early years (p. 134). However, the Australian government has invested in three programs to develop young children's STEM dispositions and capabilities: *Little Scientists*, *Let's Count,* and the *Early Learning STEM Australia (ELSA)* project (Simoncini & Lason, 2018).

Little Scientists

*Little Scientist*s, a German designed program has been integrated into Australian early childhood centres to introduce STEM education in early childhood. "*Little Scientists* is a not-for-profit initiative designed to facilitate children's natural curiosity for STEM in the early years through child-appropriate, fun, and playful experiments and inquiry-based learning," (MacDonald et al., 2020, p. 353). A study conducted in Australia by MacDonald et al. (2020), looked at the integration of the *Little Scientists* program across Australia and invited over 600 participants of the program to engage in their study. Of these participants, five small groups, called Professional Learning Networks (PLN), were established with 30 educators from across the country. These educators participated in a range of *Little Scientists* professional development workshops which included different STEM topics with the aim of building educator's confidence around implementing STEM activities with young children through inquiry questioning (MacDonald et al., 2020).

After collaborating within the individual PLN, educators then engaged in a combination of face to face and online meetings. This allowed them to discuss what they had found after implementing the programs with the children in their centres and scaffold ideas off one another. It was found that through the *Little Scientists* program children started displaying some STEM capabilities including hypothesising, predicting, problem solving, sorting, planning and designing. Participating children started using scientific language and their dispositions towards STEM activities were positive as well as towards learning in general (MacDonald et al., 2020). This study demonstrated that the intentional inclusion of STEM activities through play and inquiry-based learning can aid in developing children's STEM capabilities and dispositions whilst also creating positive dispositions for learning in general. It also reinforced the notion that young children will be more inclined to participate, be engaged and intrinsically motivated to learn when STEM activities are play-based and developed from their interests.

Let's Count

The *Let's Count* early mathematics program, for young children aged three to five, was designed in Australia by The Smith Family and researchers from Charles Sturt and Monash Universities specifically for young children from disadvantaged families to develop mathematical knowledge, skills and dispositions prior to formalised schooling (The Smith Family, 2015). The program involved educators helping families within their settings to observe and extend their children's mathematic learning in the home environment and everyday life (MacDonald, 2015). The program is underpinned by the belief that young children are competent and capable learners, and stresses the importance of learning about mathematics through play prior to formalised schooling to lay the foundation for further mathematic learning (MacDonald, 2015). As many parents and educators report they do not have adequate mathematic knowledge, they can be reluctant to introduce young children to many mathematic concepts and ideas. Through the *Let's Count* program, parents and educators build on their confidence towards mathematics learning. Educators were given professional development around the program to build their confidence as well as build the capacity to pass on this knowledge to parents (MacDonald, 2015). Educators would write learning stories about the mathematic learning that occurred with participants when they met with families. Within these learning stories the educators "unpacked" the learning, looking not only at concepts such as counting but principles within such as one-to-one correspondence and stable number order (MacDonald, 2015, p. 91).

MacDonald (2015) evaluated the *Let's Count* program. The study involved 18 early childhood educators who had participated in the program, and it was found that after engaging, the educators had increased confidence in exposing mathematic concepts to young children and were able to identify the mathematics in everyday learning. They successfully built partnerships with families and assisted them with extending their children's mathematic learning at home, and also built on parent's knowledge so they felt comfortable for when their children entered formalised schooling. Lastly, the educators reported that the program developed positive dispositions to mathematic learning in participating young children which will serve them well as they begin formalised schooling (MacDonald, 2015). These results demonstrate that by providing knowledge to educators and parents, young children's mathematic capabilities and dispositions can be strengthened and carried on later into their education.

The ELSA Project

The *ELSA Project*, developed by the STEM Education Research Centre (SERC) at the University of Canberra, involved STEM learning in a digital format via applications (apps) for use on a tablet. It builds on practical knowledge children acquire from engaging in tactile, play-based STEM learning and supports STEM practices (STEM Education Research Centre University of Canberra, 2018). Currently, young children around the world are engaging more with digital technologies. However, there has been some concern expressed around the use of digital technologies with young children particularly regarding the amount of screen time they are engaging in (Ernest et al., 2014). Despite this, Larkin and Lowrie (2019) state that there has been growing evidence around the quality of screen time when children are engaging with parents, educators or collaborating with peers whilst they are using educational programs. Younger children can confidently navigate the apps on tablets using touch as they do not require complex fine motor skills, making it more appropriate for use in early childhood rather than the use of laptops and computers with a mouse (Larkin & Lowrie, 2019). The ELSA apps are play-based, with young children then able to transfer the knowledge learned into real life situations. During the pilot year of the *ELSA Project*, the designers produced the “experience, represent, apply” (ERA) heuristic which first involved young children engaging in play-based, hands-on activities, being their *experience*, secondly engaging with the concepts from their experience in an app that *represents* STEM concepts and lastly they *apply*, building on what they have learnt in the apps to activities guided by parents and educators (Lowrie & Logan, 2019, p. 74). Larkin and Lowrie (2019) reported that educators were uncertain about digital technology use with young children and did not feel confident, but after engaging in workshops they felt better prepared to use these technologies with children and how they could do it in an appropriate manner. With the introduction of the heuristic, Lowrie and Logan (2019) also reported increased educator agency when it came to STEM, and they were able to contextualise the apps to suit their settings.

Common Themes from the Three Australian STEM Programs

In all three programs, educators initially reported low confidence towards teaching STEM to young children, but through workshops and training, their confidence grew and positive outcomes for children were observed As STEM education in early childhood is vital for future learning, educators need to feel confident around planning and delivering STEM activities and experiences with young children. Therefore, professional development can help early childhood educators feel confident in delivering STEM education within their settings and increase the number of young children exposed to high quality STEM education. Another important outcome was that STEM capabilities and dispositions were increased not only for young children, but also for educators and parents.

Australian STEM Education Research

Campbell et al. (2018) conducted a study between 2015 and 2017 with approximately 150 young children aged four and five. The children's learning was observed in both indoor and outdoor environments whilst engaging in science, mathematics and technology activities. After the STEM learning had occurred, researchers interviewed the educators and reported that in the indoor environment, learning occurred through the arrangement of the physical environment and the resources within, with most of the STEM activities being predominantly science or mathematics based. In the outdoor environment, children's imaginations were put to greater use without the use of 'toys', and creative play was more prevalent in the outdoor setting. They also found that most educators were uncertain of how to integrate STEM learning and were more inclined to plan STEM as individual subject areas (Campbell et al. 2018). This study revealed that the indoor environment, the resources within, and how it is arranged play a vital role in STEM education, but educators were not comfortable with incorporated integrated STEM, technology and engineering in this setting.

Another study conducted by Knaus (2017) also found that educators were not confident in teaching mathematics in the early childhood setting. The study, involving three early childhood centres across Western Australia, examined educator's perceptions of teaching mathematics, the types of mathematics being taught and any changes in educator perceptions of mathematics after engaging in professional development. It was found that 17 of the 21 participants did not feel confident teaching mathematics to young children. Further, 18 participants reported negative associations with mathematics from their own negative experiences at school and those who had positive experiences said their educators had made it fun (Knaus, 2017). After engaging in two professional development (PD) sessions, 15 educators reported their mathematic teaching improved and many stated they were initially teaching mathematics concepts but were not aware. This highlighted the importance of equipping early childhood educators with the knowledge and skills to teach mathematics to young children and recognise mathematics learning in everyday activities (Knaus, 2017). After conducting the professional development sessions, the frequency of mathematical concepts found in the educators' Learning Stories, pre and post PD sessions, included:

number, measurement, pattern, problem solving, special awareness, shape and time which increased, while trial and error remained the same, and sorting decreased by half (Knaus, 2017). These studies indicate similarities to the literature around the *Let's Count* and the *ELSA projects* where educators reported negative dispositions towards teaching STEM as they felt they did not have the skills or understanding to do so. However, through workshops and professional development, educators felt empowered with the skills and knowledge to implement more STEM in their settings.

The Importance of STEM in Early Childhood Education

Not only is it important to introduce STEM in early childhood so that negative dispositions are avoided and for the development of STEM capabilities, but also the characteristics that young children lend themselves to STEM ideas and concepts (Simoncini & Lason, 2018). Young children are naturally inquisitive about the world around them and have an eagerness to discover and learn through tactile experiences. It was once thought that young children were not capable of understanding STEM concepts and practices, and therefore it was introduced later as adolescents. However, it is now known that young children are capable and by introducing STEM education in early childhood, young children can develop STEM capabilities and dispositions while those exposed later in life can fall behind (McClure et al., 2017).

In the early childhood setting, STEM can be incorporated into the curriculum in an integrated, play-based approach through hands-on, child centred activities. Educators use children's interests to engage children in the activity, intentionally teaching STEM concepts in a way that is fun, age appropriate, relevant, and meaningful to the children.

Summary of STEM Literature

While there are a number of studies around STEM in early childhood education that focus on science, mathematics and technology, there is a lack of literature regarding STEM engineering and design in early childhood. This research project aimed to assist in filling the gap in STEM engineering and design literature specifically for young children, and to assist early childhood educators in building their confidence to introduce engineering and design practices in their settings, in this key STEM component.

2.4 The Engineering Design Process

Of the minimal literature around engineering and design, Kennedy and Odell (2014) state that:

> *curricula that engage students in STEM promotes instructional strategies that challenge students to innovate and invent. This indicates students have to apply the science and mathematics knowledge they learn to an engineering problem and utilize technology in finding a solution* (p. 254).

Due to the lack of interest and need for people in STEM related fields, as reported by Kelley and Knowles (2016), it has become an integral part of the early childhood curriculum with science, technology and mathematics being established learning areas in the Australian curriculum. Engineering design processes are applied through these three learning areas but due to the integrated nature of engineering, early childhood educators may not be as confident with incorporating design processes into their curriculum (Park et al., 2016). There is limited research regarding engineering in early childhood settings, but it is slowly increasing, indicating a desire for this topic to be explored (Lippard et al., 2017).

Recently, Lippard et al. (2017) conducted a study on the published engineering research of three to five-year-old children. Their aim involved developing engineering thinking in children through promoting engineering education. They utilised constructivist theories as a theoretical perspective stressing the importance of intentionality such as the materials provided for children to use (p. 463-465). Pantoya et al. (2015) stressed the importance of introducing STEM to children in early childhood and developing a positive 'engineering identity'. This involves exposing young children to the engineering design process and what engineering entails. DiFrancesca et al. (2014) stated engineering to be, "the practical application of scientific knowledge to solve everyday problems" (p. 50), whereas the engineering design process involves young children engaging in the practices of the engineering field through solving engineering problems. Murcia et al. (2020a) developed an Inquiry Questioning Model that offers prompts to educators as to the types of open-ended questioning that can be used with children when guiding the engineering design process. This inquiry questioning allows children to engage in higher order thinking and encourages problem solving (Murcia et al., 2020a).

2.5 Creativity in Early Childhood

Implementing engineering design processes in early childhood settings can help to foster children's creativity by encouraging children to problem solve and develop higher order thinking skills through open ended questioning. Pantoya et al. (2015) reported an increase in children's engineering identity during their research, as well as an increase in children's creativity through implementing engineering literature. Sternberg (2007) reported that creativity is in decline and according to Yates and Twig (2017), there has been a trend away from creative experiences in early childhood classrooms to children producing identical products, while lessons are adult-directed and involve learning about techniques instead of encouraging young children's creativity. Aubrey and Dahl (2013) discuss features of the Reggio Emilia schools in Italy including their project approach that incorporates art, science and mathematics, chosen based on educator observations of children's play or curiosity in engaging children's minds and imaginations.

Guilford (1950) described creativity as a personality trait, whereby all people show varying levels of creative behaviour through inventing, designing, contriving, composing and planning. He discussed examples of creative tests which Torrance (1977), another pioneer in creativity research, used to guide his development of the *Torrance Tests of Creative Thinking.* Torrance's tests have subsequently been commonly used worldwide as a method for measuring children's creativity. Torrance (1977) emphasises the importance of problem solving, creative thinking, and decision-making above recall and reproduction. He stated that through manipulative, exploratory and experimental activities, young children can begin to develop creative thinking.

More recently, Robert Sternberg established the notion of creativity as a habit. He has stated that creativity is not an innate characteristic, but an attitude towards life whereby individuals improvise and showing flexibility when problem solving (Sternberg, 2007). He advises use of the *12 keys for developing the creative habit in children*, one of which is the inclusion of integrated learning, and Sternberg offers mathematics, science and social studies examples. By incorporating integrated STEM into early learning curricula, it is possible to facilitate children's creative habits (Sternberg, 2007). Plucker et al. (2010) drew upon creativity research and literature to create their own definition of creativity as "the interaction among aptitude, process and environment by which an individual or group produces a perceptible product that is both novel and useful as defined within a social context" (p. 90). According to Plucker et al. (2010), an indication of one's creativity is not only the process of creating a product but also the product that has been created itself. Plucker at al. (2010) also made a connection between theories of constructivism and creative thinking as children creatively construct their own knowledge. This highlights the need to apply social constructivist and constructionist approaches to develop children's creative thinking.

In 1962, Mel Rhodes developed the *Four Ps of Creativity* model. These are product, person, process, and press. From there, Michael Resnick (2017), a professor at the MIT Media Lab, helped to develop a programming software called *Scratch w*hich enables children to develop coding skills. He believed that children develop creative thinking through four guiding principles: projects, passion, peers, and play. He states that these Four Ps are not new ideas but are built on creativity literature. Resnick (2017) stated that the creation of projects helps to develop a deeper understanding of the creative process as well as passion about the project. Engaging in meaningful discussion with peers through play promotes risk taking and trying new things. This aligns with Papert (1993) that children need to create through project work and that the socialisation during the project work from not only the educator but also peers, allows children to develop their creative thinking.

Murcia et al. (2020b) developed the *A to E of Creativity Framework*, which explores Rhodes' (1961) *Four Ps of Creativity* which includes product, person, process, and place. Figure 2.1 presents the *A to E of Creativity Framework* as devised by Murcia et al. (2020b).

<table>
<tr><th colspan="5">PRODUCT: Criteria for creative outcomes</th></tr>
<tr><td colspan="3">ORIGINAL</td><td colspan="2">FIT-FOR-PURPOSE</td></tr>
<tr><th colspan="5">PERSON: Perspectives on who does the original thinking</th></tr>
<tr><td colspan="2">CHILD ENGAGED BY EDUCATOR'S CREATIVITY</td><td colspan="2">CHILD'S CREATIVE DOING</td><td>CHILD'S CREATIVE THINKING</td></tr>
<tr><th colspan="5">PLACE: Elements of an enabling environment</th></tr>
<tr><td colspan="2">RESOURCES</td><td colspan="2">COMMUNICATION</td><td>SOCIO-EMOTIONAL CLIMATE</td></tr>
<tr><td colspan="2">Intentional provocations</td><td colspan="2">Intentional learning conversations</td><td>Stress and pressure free environment</td></tr>
<tr><td colspan="2">Stimulating materials</td><td colspan="2">Hearing and valuing children's ideas</td><td>Non-prescriptive</td></tr>
<tr><td colspan="2">Adequate materials for everyone</td><td colspan="2">Open inquiry questioning</td><td>Non-judgemental</td></tr>
<tr><td colspan="2">Time for creative exploration</td><td colspan="2">Facilitating dialogic conversations</td><td>Allowed to make mistakes</td></tr>
<tr><th colspan="5">PROCESS: Characteristics of children's creative thinking</th></tr>
<tr><td>AGENCY</td><td>BEING CURIOUS</td><td>CONNECTING</td><td>DARING</td><td>EXPERIMENTING</td></tr>
<tr><td>Displaying self-determination</td><td>Questioning</td><td>Making connections</td><td>Willing to be different</td><td>Trying out new ideas</td></tr>
<tr><td>Finding relevance and personal meaning</td><td>Wondering</td><td>Seeing patterns in ideas</td><td>Persisting when things get difficult</td><td>Playing with possibilities</td></tr>
<tr><td>Having a purpose</td><td>Imagining</td><td>Reflecting on what is and what could be</td><td>Learning from failure (resilience)</td><td>Investigating</td></tr>
<tr><td>Acting with autonomy</td><td>Exploring</td><td>Sharing with others</td><td>Tolerating uncertainty</td><td>Tinkering and adapting ideas</td></tr>
<tr><td>Demonstrating personal choice and freedom</td><td>Discovering</td><td>Combining ideas to form something new</td><td>Challenging assumptions</td><td>Using materials differently</td></tr>
<tr><td>Choosing to adjust and be agile</td><td>Engaging in "what if" thinking</td><td>Seeing different points of view</td><td>Putting ideas into action</td><td>Solving problems</td></tr>
</table>

Figure 2.1 The A to E of Creativity

According to Murcia et al. (2020b), place is the element which make the environment conducive to creativity. This can include the resources available to the children, the communication between the educator and the children and the socio-emotional climate such as the educator's pedagogy around children making mistakes and allowing them to express themselves freely. Place was formerly known as 'press' in Rhodes' Four Ps of Creativity. In terms of the product, Murcia et al (2020b) note that it must be original and fit-for-purpose as the criteria for creative outcomes. Person is defined as the individual who is doing the original thinking, and this could be the child who has been engaged by the educator's creativity, a child's creative doing or a child's creative thinking. Lastly, process involves the characteristics of children's creative thinking:

> *Five characteristic clusters, articulating what children are demonstrating when they are acting and thinking creatively, are synthesised from the literature and described as the 'A' to 'E' of children's creativity. These clusters are: Agency, Being Curious, Connecting, Daring and Experimenting* (p. 1401).

A child demonstrating agency may include self-determination, being intrinsically motivated to solve a problem or complete a task. Being curious could look like questions being asked whilst connecting might be a child drawing together two ideas or objects to propose something new. A child exhibiting uniqueness, being prepared to be different would be daring, and experimenting could be a child generating a solution to solve a problem (Murcia et al. 2020b).

These definitions and characteristics of creativity, drawn from Guilford (1950), Torrance (1977), Sternberg (2007), and Murcia et al. (2020b) have informed this study and were used to devise the indicators of creativity checklist as a means for monitoring children's creativity.

2.6 The Importance of Play-Based Learning

Play is crucial to development in the early years but in the past has been classified as a behaviour that is frivolous and of little importance (Howard, 2017). It is now known that play helps children to make sense of the world around them (Charles & Bellinson, 2019). The Australian Government Department of Education, Employment and Workplace Relations developed the Early Years Learning Framework (EYLF), *Belonging, Being & Becoming*, a curriculum document which is used to guide educator's practice in early childhood settings across Australia. The EYLF (2009) defines play-based learning (PBL) as, "a context for learning through which children organise and make sense of their social worlds, as they engage actively with people, objects and representations" (p. 6). PBL uses children's interests, strengths, and developmentally appropriate activities to enhance learning dispositions and development, engaging children through intrinsic motivation (Taylor & Boyer, 2020). PBL is not just leaving children to their own devices to play all day. While it does include some free play, there is also intentionality in the conversations between educators and children to scaffold learning. Subsequently, educators plan activities that extend children's interests in ways that are pleasurable, engaging, and exciting whilst children unknowingly learn valuable skills, concepts and ideas (Barblett et al., 2016). The Government of Western Australia Department of Education (n.d.) identifies three types of PBL. These include child initiated, guided and adult led:

> *Child initiated play is when play is chosen by the child, there is minimal direct adult involvement or interaction and it is spontaneous. When a child engages in guided play, it may be initiated by either the child or the adult and adults may join to extend learning through questioning or demonstrating. Adult-led play is organised and directed by an adult and may include instructions but remains open ended, and intentions are clear, specific and promote high level thinking skills* (The Department of Education Western Australia, n.d., p. 3).

PBL is underpinned by the constructivist approach whereby play is considered vital in developing cognitive ability, as Piaget's *Theory of Cognitive Development* states that children learn by constructing their own knowledge through their experiences of doing (Taylor & Boyer, 2020). However, Barblett et al. (2016) reported that early childhood educators in preschool settings often feel a push for more academically structured activities rather than play. The literature states that play is important in the early years for children's development, therefore it is even more important that educators of children from birth to age five are supporting play-based education in their settings and advocating for this approach (Barblett et al., 2016). As children learn through play, it becomes imperative that educators approach STEM activities in early childhood based on children's interests, in ways that are relevant and meaningful, allowing children to explore, imagine, and create.

Play-based learning alone is not enough to ensure young children are learning important concepts, skills, and ideas (Edwards, 2018). Educators also need to be intentional in their conversations with children, with how they set up in their environments, and how they scaffold and extend children's learning. The Australian EYLF states that, "intentional teaching is deliberate, purposeful and thoughtful," (p. 18).

2.7 Intentional Teaching

Intentional teaching, as defined in the EYLF, allows for social collaboration, learning experiences and interactions that foster high-level thinking and build on children's knowledge using strategies such as modelling, demonstrating, questioning, explaining, engaging in shared thinking and problem solving (Australian Government Department of Education, Employment and Workplace Relations, 2009). However, Lewis et al. (2019) reported that early childhood educators are unsure of how intentional teaching fits into a play-based curriculum. Some educators report a contradiction between intentional teaching and play-based learning, feeling that in order to cater for a play-based learning environment, educators needed to only engage in child-initiated activities and conversations. Leggett and Ford (2013) consider the notion of intentional teaching and learning where the intentional educator finds ways to create intentional learning within children. They noted that: "As educators we can employ strategies such as guiding, facilitating, scaffolding, supporting and co-constructing in order to direct children toward outcomes for learning" (p. 43). Lewis et al. (2019) discussed intentional teaching as educators having a more active role rather than reactive, and that planning and knowledge of content was imperative to intentional teaching.

Edwards (2018) described three types of play: open-ended play, modelled play, and purposefully framed play. These three types of play are similar to The Department of Western Australia's three types of PBL outlined previously, of child-initiated, guided and adult-led. When all three types of play are included in a play-based setting, intentional teaching and PBL can go hand in hand. Edwards (2018) found that educators or children did not prefer one type of play over the other and believed that each type of play had a purpose. If learning is adult-led or purposefully framed, experiences should be presented in ways that are fun, meaningful, and based around children's interests, allowing children to engage and learn concepts educators are intentionally teaching.

2.8 Inquiry-Based Learning

As well as PBL, another educational approach applicable to early childhood STEM is Inquiry-based learning (IBL). IBL allows for children to be active participants, starting with a question or a problem to solve (Chu et al., 2016). Educators facilitate learning by asking questions rather than giving children the answers. In some inquiry-based projects, children may produce an end product, but it is as much about the learning that occurs during the process as creating a product. The process of inquiry allows children to develop dispositions such as creativity, problem solving skills, and collaboration (Chu et al., 2016). Krogh and Morehouse (2020) state that "For young children (and for many older ones and adults as well), the most effective approach to enthusiastic and truly successful learning is one of using inquiry through an integrated curriculum" (p. 6). The foundation of IBL as an educational practice emerged through the works of John Dewey (1859-1952), who believed that students should think and act scientifically rather than just be taught scientific facts (Lazonder & Harmsen, 2016). IBL is also relevant to Piaget's beliefs about how young children learn mathematics, by constructing knowledge through discovery and solving problems that are of interest as opposed to rote learning (Krogh & Morehouse, 2020). It also fits with Malaguzzi's Reggio Emilia school's project-based model. Ward and Damjanovic (2020) explored the development of numeracy in children aged three to five using play and IBL through integrated learning and the children's interests. Their study reported that project work, along with educator questioning, assisted in developing young children's mathematical knowledge. Berson et. al. (2019) conducted a study of children aged three to five years old using tangible, digital technologies with the IBL approach. They reported positive social and emotional outcomes for the children involved and rich language opportunities through IBL and inquiry questioning. As mentioned previously, play-based learning and intentional teaching have been described as contradictory to each other, but IBL fits across both categories. Krogh and Morehouse (2020) consider IBL can meet outcomes for children in a way that can be playful and fun.

2.9 The Cycle of Planning

Planning and documentation is an important component of early childhood pedagogy. In the early childhood setting, educators follow a cycle of planning to promote and assess children's learning and development. In order for intentional teaching to be successful, the educator must plan and understand the concepts they are trying to teach (Lewis et al., 2019). The Australian Children's Education and Care Quality Authority, ACECQA (2015) states that, "The cycle of planning helps educators to purposefully support children's continual learning and design meaningful learning opportunities," (para. 3). The cycle begins with collecting information about the child or children in the setting. Information must be relevant and meaningful, and can come from a variety of sources including educator's observations and input from families (ACECQA, 2021). After gathering the information, educators then question and analyse to interpret the learning that has occurred and how it can be extended

(ACECQA, 2021). Educators then create a plan to extend children's learning based on the information collected and analysed. The plan is then implemented and reflected upon to complete the cycle (ACECQA, 2021). As the last step, reflection and evaluation of the cycle allows educators to look critically at their practice, evaluate children's learning and the effectiveness of the experiences that have been offered, communicate with families, take note of the individual child's outcomes of learning and development, and use this information to create new opportunities for further learning (ACECQA, 2021).

2.10 The Purpose of Learning Stories

A learning story is an assessment tool used to document, analyse and reflect upon children's learning. It was originally designed in 1990 by Margaret Carr for specific use in early childhood centres and is the main assessment tool used for the New Zealand early childhood curriculum, *Te Whāriki* (Knauf, 2018). Learning stories can be used as part of the cycle of planning as they include information about what a child is doing, often in a storytelling format, an analysis of the learning that has occurred, how the learning can be extended, and the educator's reflection.

In 2009, the Harvard Graduate School of Education (cited in Lowe et al., 2013) created the Visible Thinking Routine: *I See, I Think, I Wonder*. The thinking routine was originally designed for use with children in developing critical thinking in visual arts, but can be used in other contexts (Lowe et al., 2013). It can also be incorporated into learning stories to assist educators in their critical thinking and reflection. When observing a child, the educator first documents what they see the child doing, what they hear the child say and any nonverbal communication that the child is engaging in whilst taking photographic evidence. The educator then decides whether the learning is meaningful enough to be written into a learning story. They begin writing as a story or observation. If using the Harvard Visible Thinking Routine, this would comprise the *I See* section, writing literally about what the educator saw the children doing. Next, the educator analyses the learning that has occurred. This part of the learning story comprises the *I Think* section where the educator states what they think the children's learning could be. Lastly, the educator uses that information to reflect and then plan for possible future learning, writing what they wonder about in terms of their practice or the extension of children's learning (Lowe et al., 2013).

Overall learning stories provide a valuable holistic view of the child's learning which capture learning dispositions as well as developmental and subject areas (Knauf, 2020).

2.11 Critical Reflection to Inform Practice

As part of the planning cycle, educators critically reflect upon their practice, ideas, and children's engagement after implementing activities and experiences. Critical reflection is not just a recount of events or how the activity could be extended. It involves the educator thinking deeply about how their practice can be improved, their intentionality, whether the learning activity was engaging, relevant and meaningful or whether there were other learning opportunities that could have been included (ACECQA, 2017). It also includes looking at levels of engagement among the children and understanding personal biases including gender, race, and ethnicity stereotypes as well as privilege and economic status (Anderson, 2014). Morley (2019) states that, "critical reflection involves higher order thinking, drilling down and using multiple perspectives and creative thinking. These aspects are often missed by educators and are sometimes challenging to understand and use" (para. 1). By reflecting in this manner, educators can change their pedagogy and practice to become better practitioners and professionals. Anderson (2014) states that "engaging in critical reflection is the first step in changing the dialogue and transforming early childhood education" (p. 82). Within a learning story, critical reflection comprises the *I Wonder* component of the Harvard Visible Thinking Routine (Lowe et al., 2013).

2.12 Chapter summary

This study is framed within social constructivism as its broad theoretical perspective, utilising constructionism as defined by Papert (1993) as its research lens, with participants in the study constructing their own knowledge through the creation of tangible objects. As described in chapter 1, cycle one included participatory children creating a variety of tangible objects using any items provided in the research setting. Cycle two involved the children making a boat that floats and cycle three incorporated the children creating a bridge with recycled materials from both cycles two and three. I chose to draw upon play-based learning, intentional teaching and inquiry questioning as strategies to inform the teaching and learning of STEM education and the engineering design process, to encourage children's creativity.

The resulting conceptual framework, drawn from this review of the literature and which guided this study, is presented below in Figure 2.2.

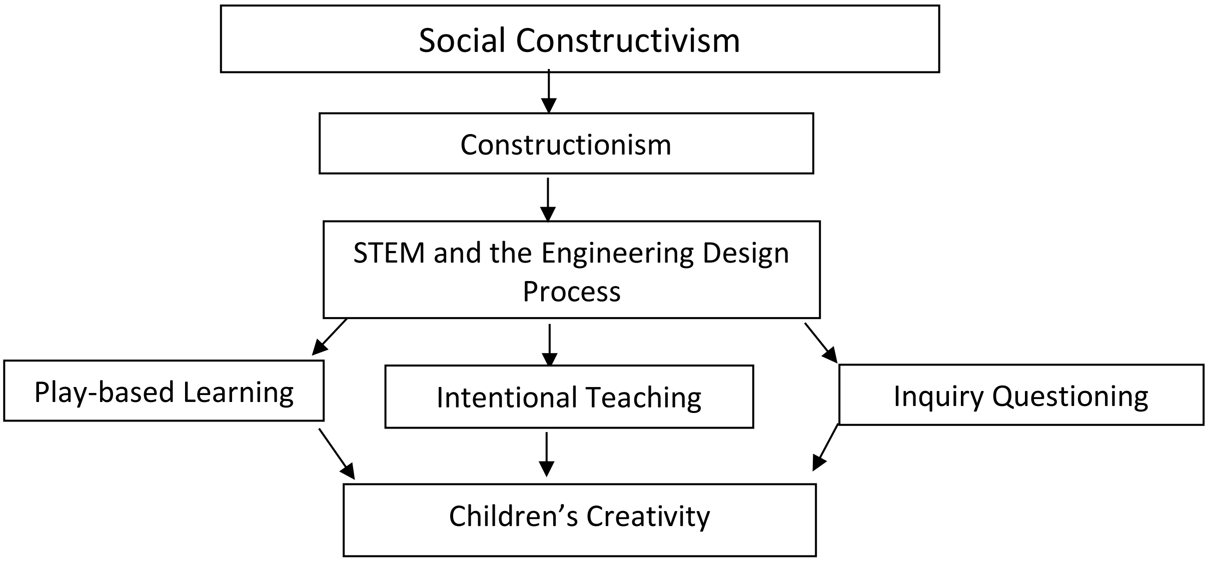

Figure 2.2 Conceptual Framework

Given the aim of this study to investigate a STEM engineering design process in an early childhood centre, a review of the literature has indicated the importance of social constructivism in terms of understanding how young children learn, and the value of constructionism in terms of developing concrete outcomes in a STEM setting. Further, the literature review has revealed the importance of understanding the role of creativity and the importance of encouraging it in early childhood STEM settings. Finally, the chapter has discussed various teaching approaches suited to encouraging creativity and the importance of educator reflection in improving practice. All these elements have influenced the design and implementation of this study and will be discussed in the next chapter where the research methods are presented in detail.

Chapter 3. Methodology

3.1 Introduction

The previous chapter presented a detailed literature review which outlined the theories of social constructivism and constructionism, STEM in early childhood with emphasis on the engineering design process, and theories of creativity in early childhood. It then went on to discuss play-based and inquiry-based learning, the cycle of planning, learning stories, and critical reflection. It concluded with a summary of the chapter and presented the conceptual framework which underpinned the study. This chapter now outlines the methodology used to inform the study in order to answer the research questions.

The chapter commences with an overview of the research before presenting the research paradigm, epistemological stance and action research as the methodological approach utilised in this study. In the second part of the chapter, details of the study are presented, including the context and participants, tools for data collection, data analysis and the ethical considerations surrounding the research.

3.2 Overview of the Research

In research, the nature of the research question informs the method of inquiry. In this study, the overarching research question and three sub-questions, as stated below, imply a participatory research approach (Punch & Oancea, 2014). The overarching question was:

> *How do young children respond to the intentional inclusion of an engineering design process in early childhood integrated STEM activities?*

The three sub-questions were:

- *How can an engineering design process be adapted and implemented in young children's play (3 and 4 years old)?*
- *How can young children's development of creativity be monitored?*
- *How does the design process effect young children's demonstration of creativity?*

In order to answer the research questions, action is needed to implement and adapt an engineering design process for young children and a tool developed to monitor their creativity. I chose a case study design as I am an educator working in a specific early childhood setting. A case may be a person or group of people, a location, an event or another phenomenon (Punch & Oancea, 2014). For the purpose of this study the participants became the cases. Being a practitioner researcher, I decided on action research as a method as it is mostly conducted by educators within their own settings (Creswell, 2008). Further, due to the cyclical nature and reflective practices associated with action research, this method was chosen to address the research questions through the implementation of an engineering design process, observing the effects on young children's creativity and improving on my practices and pedagogy as an early childhood educator.

3.3 Paradigm

This research project is grounded in the constructivist paradigm which assumes that knowledge is socially constructed through experiences. Therefore, the researcher attempts to interpret the participant's views and perspectives (Creswell, 2008; Kivunja & Kuyini, 2017). Guba & Lincoln (1994) state that in this paradigm, there are multiple, intangible realities dependent on the individual who is holding the construct. Constructions are not more or less 'true', but simply more or less informed and/or sophisticated; they are alterable, as are their associated "realities" (pp. 110-111). In this study, I attempted to make sense of the participants understandings through their verbal language, with excerpts of script to support findings and non-verbal language such as the actions they make as well as the tangible objects they create.

3.4 Epistemology

Within the constructivist paradigm, this research project employed a subjectivist epistemology. This is the belief that the researcher's own background and worldviews can shape the interpretation of data and that data is inevitably collected through social interaction with the participants (Kivunja & Kuyini, 2017). This project, which involved an action research design, incorporated social interaction between myself as the researcher and the participants, where not only verbal language was used within the data collection, but also the non-verbal language of the participants. I am aware of my role in interpreting the data therefore, to guard against unintentional bias, I have remained as transparent as possible in describing what I did and what I found. My study involves an interpretivist stance, and I am aware of my role in interpreting the data. This will be discussed further in the chapter under Validity and Reliability.

3.5 Methodological approach

In choosing an action research approach in an education setting, I was conscious of the value of researcher-practitioner relationships as stated by McClure et al. (2017): "Researcher-practitioner partnerships, in which practitioners are involved as ongoing partners as early as the research design stage, play an essential role in supporting the iterative process of education reform" (p. 9).

An Introduction to Action Research

Piggot-Irvine et al. (2015) define action research as "a collaborative transformative approach with joint focus on rigorous data collection, knowledge generation, reflection and distinctive action/change elements that pursue practical solutions" (in Cohen et al., 2017, p. 441). Action research is mostly conducted by educators in their own setting with the aim to improve issues in the classroom or community as well as their own practice (Creswell, 2008). There may be one person or multiple people, who are involved in education, conducting the research on a topic of interest to them (Fraenkel et al., 2012). An action research project may include a 'critical friend' or 'collaborator' that works with the practitioner-researcher (Punch & Oancea, 2014), and this 'critical friend' may be an experienced researcher from a university or other organisation (Foulgar, 2010). Action research can help solve local problems, but it can also help others in a similar situation to solve the same problems. Further, it can inspire others in completely different locations to begin their own action research project within their own context (Johnson & Christensen, 2012).

As a process of inquiry, action research is cyclical in nature and allows for reflective practice (Creswell, 2008). There are many different approaches and names given to action research but most of these methods share common traits (Kemmis et al., 2014). The following discuss the origins and advocates of action research, the different stages and types as well as different ways of collecting data, and the advantages, concerns and criticisms of action research.

Action Research Origins

Kurt Lewin, a social-psychologist, was a key contributor to the concept of action research in the 1930s and 1940s and he conducted his research with factory workers after World War Two (Adelman, 1993; Creswell, 2008). He believed that through collaboration, action and reflection, ordinary people could conduct research about everyday problems and that it would assist in solving social issues (Adelman, 1993; Tomal, 2010). Lewin (1946) described the process of action research as being "rational social management" as it "proceeds in a spiral of steps each of which is composed of a circle of planning, action, and fact-finding about the result of the action" (p. 38). During the next few decades there was a decline in the use of action research as a methodology. In the 1970's, action research re-emerged in some western countries with educational researchers advocating for and developing research projects (Punch & Oancea, 2014). One of these researchers, Lawrence Stenhouse, advocated for practitioner-researchers. He described the classroom as a laboratory, and that educators being at the forefront of the classroom should be encouraged to participate in research (Stenhouse, 1981). Stenhouse (1981) stated:

> *Using research means doing research. The educator has grounds for motivation to research. We researchers have reason to excite that motivation: without a research response from educators our research cannot be utilized* (p. 110).

Since Lewin's original model of action research, Kemmis et al. (2014) developed critical participatory action research. In their critique of Lewin's model, they stated that his focus on the cycle oversimplified the process and promoted the outsider or consultant as researcher rather than being actively involved and participating in the research (Kemmis et al., 2014). Critical participatory action research involves a focus on making a social change be it for gender and race discrimination or sustainable practices. It does not emphasise exactly following the steps of the action research model, rather that these steps can be integrated and exchanged, focusing on the authenticity of the research instead (Kemmis et al., 2014).

Stages and Types of Action Research

Stringer (1999), developed an action research spiral of looking, acting and thinking as showing the cyclical process of action (in Creswell, 2008). By contrast, Fraenkel et al. (2012) presents four steps in action research as:

1. Identifying a problem or question,
2. Gathering information or collecting data,
3. Analysing and interpreting the information/data, and
4. Developing a plan of action.

Lewin's model of action research provided two more stages in addition to the four above, including:

5. Taking action (implementation), and
6. Evaluation and follow up (as cited in Tomal, 2010)

In the initial stage, when identifying a problem or question, an educator might have an issue in their setting or community that they would like to solve (Creswell 2008). Identifying a problem or question may not be the first stage of the research as it is a cyclical process and could be developed after data collection or at other stages.

Data collected in action research can be qualitative, quantitative or a mix of both (Creswell, 2008), and may include interviews, observations, experiments, surveys or instruments often made by the educators specific to the setting (Fraenkel et al., 2012). Action research is usually described as a qualitative approach, but it allows for quantitative data use when appropriate (Punch & Oancea, 2014, p.172). During the second stage, educators can be active participants or non-participants. An active participant may be involved with teaching the lesson whereas the non-participant observes how the students work and interact together (Fraenkel et al., 2012). Either way, the data collected must be objective and action researchers should avoid using only anecdotal data when gathering information as this simply provides opinions which do not allow for a broad, unbiased and accurate research project (Fraenkel et al., 2012).

Tomal (2010) states that before an educator begins to analyse data, they must understand validity and its threats including maturation of the participants (especially of those in the younger years), instrumentation or the method of data collection attrition or the loss of a participant, the *Hawthorne Effect* whereby participants perform better due to being observed, researcher bias and contamination. During this stage the researcher can use descriptive statistics, graphs and diagrams to better understand their data and the need to reflect is imperative (Tomal, 2010). Fraenkel et al. (2012) stress the importance of analysing the data in accordance with the research question with the aim to solve the stated problem. When taking action, educators use the findings from the analysed data to implement changes (Fraenkel et al., 2012). Evaluation involves reflecting about whether the changes implemented have solved the research problem. Due to the cyclical nature of action research, evaluation may generate new problems, or the researcher may decide to revisit previous stages (Tomal, 2010).

Over time, there have been numerous variations on the action research stages, many of which are similar to Lewin's model of action research. Fraenkel et al. (2012) describe two types of action research, 1) practical action research and 2) participatory action research. Whilst both aim to resolve issues, practical action research focuses on problems in the classroom and improving educator performance whereas participatory action research focuses on solving issues in the community and in society (Creswell, 2008).

Advantages and Concerns of Action Research

Fraenkel et al. (2012) state that the advantages of action research include improving educational pedagogy and educator practice and other individuals in education settings. It allows for like-minded people to connect through current, relevant research in their local community (Fraenkel et al., 2012). For educators, the convenience of conducting a research project in the workplace is also an advantage.

Creswell (2008) believes that action research encourages educators to reflect on their practices whilst empowering them to, in turn, create change in local settings but others have queried this assertion. Johnson & Christensen (2012) believe that action research can add to broader knowledge in the field if those participating in action research publish their findings and present them at conferences. Cochran-Smith and Lytle (1993) argued that “with educator research, knowledge will accumulate and be made more public as communities of school-based and university-based educators and researchers read and critique one another’s work” (cited by Helskog, 2014, p. 13). Stenhouse (1981) states that educators conducting their own research allows for a more realistic inquiry as opposed to the educator applying the findings of outside research to solve an issue in the classroom. He believes that “using research means doing research” (p. 110). Mertens (2007) believes that “action research is a necessary, if not sufficient, element of a transformative paradigm, as it involves people as equals (in Cohen et al., 2017, p. 53). Cohen et al. (2017) also states that action research has the power to affect local change.

There have been some studies into training pre-service educators in action research methods to improve educator practice and student learning. Kitchen and Stevens (2008) found most pre-service educators in their study benefited from conducting action research projects during their practicum. In addition, their students became more motivated and engaged in their lessons. Another study of pre-service educators using action research by Conroy (2014) involved participants using action research in their special education practicum. Similar results were obtained with participants reporting benefits from the project and intentions to use action research in their future teaching.

Action research has its critics who believe it is not a research methodology as often educators lack formal training and research knowledge (Fraenkel et al., 2012). Cohen et al. (2017) questions whether action research has the power to make changes at a national or international level. They question whether action research genuinely empowers educators as it has little impact upon broader policy making outside of their specific educational setting. Kitchen and Stevens (2008) found some of their pre-service educators did not benefit from action research methods. They found it difficult to generate research questions and topics of interest, and believed the research project was "useless" (p. 21). This made the researchers question whether pre-service educators have enough knowledge and experience in teaching to be conducting action research (Kitchen & Stevens, 2008, p. 21). Even so, as the majority reported it to be useful, they also believed they would carry on their knowledge of action research into their teaching careers. Training pre-service educators in action research may assist in justifying action research as a methodology. By providing training for future educators, they in turn have prior knowledge and experience of action research to take with them into their prospective careers. In addition to training for pre-service educators, involving a 'critical friend' can provide practitioner-researchers with some knowledge of research and an outside perspective in guiding an unbiased, in-depth project (Foulgar, 2010).

The lack of training and knowledge of educators conducting action research are not the only concerns of others. Some question the validity of action research due to data bias and concerns as to the limited generalisability of the findings (Fraenkel et al., 2012). This is something that action researchers need to be aware of. However, Stenhouse (1981), stated that action research as a data collection method did not usually show bias. He said:

> *This is not in my view a sustainable objection. In my experience the dedication of professional researchers to their theories is a more serious source of bias than the dedication of educators to their practice. Educators whose work I have examined at master's and doctoral level seem to me to achieve remarkably cool and dispassionate appraisals. I See more distortion produced by academic battles than by practical concerns* (p. 110).

Limited generalisability is a criticism levelled at researcher projects carried out in individual classrooms. To overcome this problem, the project needs to be replicated (Fraenkel et al., 2012), and if action research educators reach out to others through publishing and conference presentations, the likelihood of their projects being replicated is greater. Another stated concern is that action research is not science and cannot bring about new knowledge and theory, as one of the main purposes of research is to develop theories and knowledge (Helskog, 2014). Kemmis (2010) challenges this, stating that "understanding is not in some sense prior or superior to action or to one's relationships with other people and the world" (p. 419). He believes that it is just as important to make history as it is creating theories (Kemmis, 2010). The assessment of action research by Argyris et al. (1985), as cited in Helskog (2014), is that it is action science, but it must be:

- Empirically non-confirmable propositions that are organized into a theory and falsified by practitioners in real-life contexts,
- Knowledge that is useful in action, so that human beings can implement it in an action context, and
- Alternatives to the status quo that both: a) illuminate what exists, and b) inform fundamental change in light of values.

For Argyris et al. (1985), if action science incorporates all three, then it involves mainstream science, applied science and critical social science (Helskog, 2014). Helskog (2014) also believes that action researchers demonstrate the same scientific criteria as 'mainstream' social scientists.

In summary, since Lewin's early contribution, action research has progressed as an educational research methodology. It has many potential advantages such as improving practice, connecting people in the education field and creating change locally and at the broader community level, but also presents some disadvantages and concerns including educators lacking research knowledge, biased and limited generalisable data as well as the belief that action research is not science. However, by focusing on the bigger picture, action research has significant relevance in research. It allows for educators to make a difference to children's learning as well as their own educational practice. Through collaboration and sharing of action research findings, other educator's educational practice can also be facilitated and in a larger sense, it can create social change. Having considered the value of action research as the methodology underpinning this project, the chapter now examines case study design in more detail.

Case Study Design

Punch and Oancea (2014) along with Miles and Huberman (1994) define a case study as:

> *A phenomenon of some sort occurring in a bounded context. Thus, the case may be an individual, or a role or a small group or an organisation, or a community, or a nation. It could also be a decision, or a policy, or a process, or an incident or event of some sort, and there are other possibilities as well* (p. 148).

Case study design involves an in-depth analysis of a specific case (Bryman, 2004; Punch & Oancea, 2014). Punch and Oancea (2014) also describe case studies as a strategy rather than a method where the researcher observes the case in its natural environment to understand the context. The popularity of case studies declined in the 1960's due to the belief that they lacked generalisability (Bryman, 2004). However, case study design re-emerged in the 1970s and 1980s as a way to collect meaningful data in opposition to the more common quantitative methods during that time (Hamilton & Corbett-Whittier, 2013).

Stenhouse (1979) was a supporter of case study design in educational research. He described two methods of data collection within a case study: 1) participant observation, and 2) collecting data through interviews. In addition, Hamilton and Corbett-Whittier (2013) identified three forms of case study. These included: 1) exploratory, where patterns are recognised in the data, 2) descriptive, where possible theories frame the study with a focus on research questions, and 3) explanatory, where the study answers or explains the how or why of the case (Hamilton & Corbett-Whittier, 2013). Merriam (2009) defines a case study as being a 'bounded system' and also states three features including: 1) particularistic, where there is a focus on a particular event, situation or phenomenon, 2) descriptive, where the end product is a "thick" description, and 3) heuristic, where there is new or greater understanding of the phenomenon.

Punch and Oancea (2014) list three types of case study as intrinsic, instrumental, and multiple or collective. Intrinsic case study involves the researcher gaining insight and more understanding of a particular case, underpinned by an intrinsic interest (Hamilton & Corbett-Whittier, 2013; Stake 1995). Instrumental case study involves investigation of an issue or theory within a case, and multiple or collective case study includes an extension of several cases (Punch & Oancea, 2014). Stake (1995) states that, "a good case study is patient, reflective, willing to see another view" (p. 12). According to Hamilton and Corbett-Whittier

(2013), researchers can employ either quantitative or qualitative methods which highlights the varied approaches to the definition and how researchers might implement a case study.

Bryman (2004), and Punch and Oancea (2014) discuss generalisability as a concern of case study design. Stenhouse (1979) emphasises the importance of taking accurate, detailed records of data and ensuring its availability after the study is complete. On this, Punch and Oancea (2014) state:

> *It is important to be clear on the rationale behind the case study, and on its purpose(s). That means clarifying the strategy of the case study, developing research questions to guide the study, reflecting on the relevant experiences available, and engaging with insights form relevant research, including research on other cases* (p. 155).

The Research Approach for This Study

Based on the preceding considerations, the overarching design for this project is set out in Table 3.1. below. The table sets out the paradigm, epistemological and methodological approach, and also includes an overview of the participants, the methods of data collection and the data analysis pathway.

Table 3.1 Research Overview

<table>
<tr><th colspan="7">Research Overview</th></tr>
<tr><td>Paradigm</td><td colspan="6">Social Constructivist</td></tr>
<tr><td>Epistemology</td><td colspan="6">Subjectivist</td></tr>
<tr><td>Methodological Approach</td><td colspan="6">Action Research
Case Study</td></tr>
<tr><td>Context</td><td colspan="6">Early Childhood Centre at a University in Perth, Western Australia</td></tr>
<tr><td rowspan="3">Participants</td><td colspan="6">6 children aged 3-4 years of age of various cultural backgrounds</td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td></tr>
<tr><td>Female</td><td>Female</td><td>Male</td><td>Female</td><td>Male</td><td>Male</td></tr>
<tr><td>Data Collection</td><td colspan="2">Documented critical reflective practice (written notes, audio recordings, learning artifacts)</td><td colspan="2">Creativity checklist</td><td colspan="2">Learning stories</td></tr>
<tr><td>Data Analysis</td><td colspan="6">Thematic analysis, Deductive analysis through a lens of creativity</td></tr>
</table>

This study is a case study-based, action research project which explored STEM with a focus on engineering and creativity in an early childhood centre. It was conducted with a group of six children aged three and four years old from a range of different cultures and genders, and the participating children were drawn from an early childhood community centre attached to a large university in Perth, Western Australia. The participants engaged in three action research cycles. In the first cycle, the children were observed in the environment creating with everyday resources and or the constant activities available to them. An engineering design process using an Inquiry Questioning Model was introduced in cycle two where the children created boats that needed to float with a doll inside. Lastly in cycle three, the children created a bridge that needed to hold three figurine Billy Goats. The rest of this chapter now outlines the specific details of this study.

3.6 Context and participants

The research site for this study offers long day care for children aged zero to five spread across six rooms. I carried out the research in this early childhood setting as team leader in the kindergarten room, referred to as the Kookaburra room. Parents and guardians of all children in the room were invited to participate. From the children who gained signed permission, a diverse group of six children were chosen. The group includes children of different genders and ethnic diversity, with some having English as a first language and others with English as a second language. The children were assigned pseudonyms to protect their identity, thus the names in Table 3.2 are not their real names. The early childhood centre, being a long day care setting, meant the attendance of the children was varied. Table 3.2 outlines the children's days of attendance along with their assigned pseudonyms.

Table 3.2 Children's Days of Attendance

Child's Name	Days of Attendance
Ava	Tuesday
Sarah	Monday, Tuesday
Adam	Tuesday, Thursday
Olivia	Monday, Wednesday (once a fortnight), Thursday,
James	Thursday, Friday
William	Tuesday

To encourage the children to join in with the activities, they were grouped not only among the other children that attended on the same day, but also within their friendship groups. Another child, Henry, started with the project but left the centre in cycle one so William took his position, staring late, therefore having to work individually for cycles one and two. Olivia also worked individually in cycles one and two as Sarah was working with Ava on Tuesdays. Ava and Sarah were in the same friendship group which generated greater motivation to participate and provided the study with a mixture of collaborative work between participants and some data of independent work.

3.7 Data collection

Observations and Critical Reflections Within the Cycles of Learning

This study involved three cycles of action as set out in table 3.3 below.

Table 3.3 Cycles of Action and Amount of Observations

Cycle	Number of Observations/Learning Stories
Cycle one: Creation using the constant resources / activities	6 Observations/Learning Stories
Cycle two: Creation of Boat for Sally	8 Observations/Learning Stories
Cycle three: Creation of Bridge for the Three Billy Goats Gruff	2 Observations/ Learning Stories

Cycle One

The first cycle of action included six observations / learning stories with me collecting data and observing the children play in the natural setting, using everyday resources. This occurred over a period of six months due to one participant leaving and a new participant joining the project. The children created a cake using playdough, a tower and dinosaurs using wooden blocks, a house with a garage using Lego Duplo, a train and satellite using Mobilo and a bus collage. From this, I decided that the next cycle of action would include the engineering design process around the theme of transport.

Cycle Two

During the second cycle of action, the participants were introduced to Sally the doll and the problem of how to get Sally across a water trough. I used an inquiry questioning design process model to plan the lessons before it was introduced to the children. Table 3.4 below shows the inquiry design process, implemented in the second stage of action, as developed by Murcia et al. (2020a).

Table 3.4 Designing: Engineering a Solution

Activity Stages	Inquiry Questioning
Asking	What is the problem? What do you know already? What do you need to ask or find out about..?
Imagining	What could you make? What would it look like?
Creating	What materials do you want? What tools do you need? What do you need to measure?
Trying out	How good is your solution?
Improving	How could you make it better?
Reflecting	Did your design solve the problem?
Reasoning	How do you know..?

To introduce the problem, I asked the children how they could get Sally the doll from one side of a trough to the other, pretending it was a river. When the children replied that they would use a boat, I showed them photos of different types of boats. There were resources included intentionally and a provocation set up to include objects that were waterproof, including plastic containers, and some that were not, including cardboard boxes. A range of other materials and tools were also provided such as sticky tape, glue, wool, string, pop sticks, scissors, Styrofoam pieces, straws, pinecones, gumnuts, corks, plastic lids, feathers, and paper bags. The resources were set up in an intentional manner, in the form of a provocation, allowing the children to use them however they pleased. The children were asked which materials they could use to make their boats and discussed whether the materials could float and if Sally the doll would fit. This is shown in Figures 3.1 and 3.2.

Figure 3.1 Provocation Tabletop Set Up

Figure 3.2 Other Resources Available

After this, the participants drew their designs based on the pictures of boats they looked at and the materials available and testing them to see if they were successful afterwards. If their boats were unsuccessful, the children were asked why they thought their boats sunk, what they could do to make their boats float and were given an opportunity to modify their designs in the next lesson. Once a boat was created that successfully floated, they were asked to reflect on what happened, whether they made any modifications to their original designs and why their original designs were unsuccessful. During this second action cycle, Adam and James took four attempts to create a floating boat, and therefore four learning stories were generated for them in this cycle. Ava and Sarah took two attempts with two learning stories while both William and Olivia each took one attempt with a learning story each. This came to a total of eight observations/learning stories. Any creativity demonstrated by the children was recorded after the observations using the prepared Indicators of Creativity checklist (see below). The timeline of the second stage of action took seven weeks and was dependent on how long it took the children to complete the process and how far they took their designs and modifications.

Cycle Three

Lastly in the third action cycle, a new inquiry questioning problem was introduced using the same design process model and once again, I planned for the lessons using the model. In this cycle, the children were asked how they could get the Three Billy Goats Gruff figurines across a river. Most of the children knew the story and said a bridge so I showed photos of a variety of bridges. The children then drew their designs, creating them afterwards. The provocation was set up with a river that was made from blue paper, artificial grass, three goat figurines and the same materials and resources used in cycle two. The children were split into two groups for this cycle with James, Adam and Olivia working together in one group and Sarah and William in another group. Another participant, Ava left the centre at this point, and it was deemed too far into the study to replace her. For both participant groups there was an observation for each as they successfully created a bridge in one observation each. Therefore, there were two observations/learning stories in this cycle which occurred over two days. This activity proved to be easier than the cycle two activity which will be explained in detail in chapter 4.

Indicators of Creativity Checklist

Data during each action stage was collated through a creativity checklist. It was developed using Guilford (1950), Torrance (1977) and Sternberg ‘s (2007) literature of creativity, and the A to E of Creativity template (Murcia et al., 2020b) and is presented below in Table 3.5.

Table 3.5. Indicators of Creatvitiy

Indicators of Creativity
Ideation (I)
I1 Asks Questions
I2 Challenges other ideas or assumptions
I3 Proposes multiple ideas for design
I4 Reflects critically on ideas
I5 Makes connections between things that are not usually connected
I6 Proposes and gives reasons for a possible solution
I7 Imagines multiple uses for an object
Creation (C)
C1 Establishes a purpose for their actions
C2 Draws together two ideas or objects to propose something new
C3 Uses an object in a way other than its intended use
C4 Modifies initial design
C5 Tries out new arrangements or approaches
C6 Generates a solution to solve a problem
Reflection and Evaluation (RE)
RE1 Reflects critically during the creating process
RE2 Reflects critically on idea and process for solving problem or constructing the product
RE3 Evaluates the product for its originality, effectiveness and being fit for purpose
Overarching Social and Emotional Capabilities
SE1 Resilience: Staying with the task even when struggling and learning from previous errors
SE2 Self-Determination: intrinsically motivated to solve a problem or complete a task
SE3 Collaboration: Playing and learning collaboratively with peers
SE4 Uniqueness: Being prepared to be different
SE4 Openness: Being receptive to novel ideas, imagination and fantasy

Using the creativity literature, the checklist was created and then divided into three stages and overarching themes to suit the engineering design process. These stages included Ideation, where the children thought about how they could create to solve the problem, Creation, where the children created their boat and bridge designs, and lastly Reflection and Evaluation, where the children reflected on their designs once each had been created and tested. As well as these stages, some Overarching Social and Emotional Capabilities were also included that indicated creativity. The Ideation stage involved seven indicators of creativity, including, 1) asking questions, 2) challenging ideas and or assumptions, 3) proposing multiple ideas for design, 4) considering a range of ideas critically, 5) making connections between things that are not usually connected, 6) proposes and gives reasons for a possible solution and 7) imagines multiple uses for an object. The second stage, Creation, included six indicators of creativity: 1) establishing a purpose for actions, 2) drawing together two ideas or objects to create something new, 3) using an object in a way other than its intended use, 4) trying out a new arrangement or approach, 5) modifying the initial design and 6) generating a solution to solve a problem. In the Reflection and Evaluation stage, there were three indicators of creativity: 1) reflect critically during the creating process, 2) reflect critically on idea and process for solving the problem or constructing the product and 3) evaluating the product for its originality, effectiveness and fit for purpose. Under the Overarching Social and Emotional Capabilities, the five indicators of creativity included: 1) resilience, 2) determination, 3) collaboration, 4) uniqueness and 5) openness.

This checklist was on hand during data collection and was used to document children's creativity. However, as I was conducting the sessions, it was not feasible to check off all the indicators during this time, so it was used whilst writing the learning stories in conjunction with audio replays. Each indicator was dated, and a colour scheme generated to distinguish between each cycle. The completed template of the checklist is provided as Appendix A.

Learning Stories and Critical Reflection

Qualitative data was also collected in the form of 'learning stories' as described in chapter 2.9. Learning stories comprised observations supported with photographs, and form part of the practice at the early childhood centre to provide evidence of children's learning. The learning stories for this study were altered slightly from the templates used by the centre and followed the *I See*, *I Think*, *I Wonder* framework where I first wrote detailed observations of the participants actions and relevant quotes in the 'Story' or *I See* section (Lowe et al., 2013). Next, I described the learning that occurred based on my observations, actions, and quotes, under the 'Analysis' or *I Think* section. Lastly, I engaged in critical reflections at the conclusion of each learning story in the 'Where to next' or *I Wonder* section. I re-listened to the audio in order to write the Story (*I See*) component, and photographs were also used to support the audio, as set out in the following data analysis section.

3.8 Data analysis

Data was analysed using deductive thematic analysis through a lens of creativity. Thematic analysis involves the researcher using a systematic approach to identify, analyse, and interpret data, and find patterns and themes to make sense of the qualitative data (Braun & Clarke, 2012; Clarke & Braun, 2017). The researcher generates 'codes' which Clarke and

Braun (2017) define as, “the smallest units of analysis that capture interesting features of the data (potentially) relevant to the research question. Codes are the building blocks for themes, (larger) patterns of meaning, underpinned by a central organizing concept - a shared core idea,” (p. 297). Deductive analysis involves the researcher testing out whether data is consistent with a theory, preconceived idea or hypothesis (Thomas, 2006).

In this study, I produced learning stories using the audio and photographic evidence collected and used this information to identify indicators of creativity for each individual child. From there, the frequency of indicators was calculated, and it was found that all indicators from cycle one to cycle two increased. However, for all but one child, the frequency of indicators from cycle two to cycle three decreased. As the number of sessions in cycle two compared to cycle three decreased from eight sessions down to just two, so did the number of indicators. Therefore, I converted the frequency of indicators into a percentage to offer a more accurate representation of the data. Having generated frequency indicators for each child individually I then did a cross case analysis, combining the frequency of indicators for each child to give a total number. I then examined the total frequencies for each indicator comparing them across the three action cycles. Afterwards, I identified the common themes within the dialogue from the learning stories, and the trends from the total number of indicators for all children to generate the overall findings and assist in answering the research questions.

3.9 Validity and reliability

Traditional research involves using statistical procedures to measure validity and reliability. However, in qualitative research validity and reliability takes different forms and the term trustworthiness is more commonly used (Stahl & King, 2017). Within trustworthiness there are four components: credibility, transferability, dependability, and confirmability (Gunawan, 2015).

Gunawan (2015) considers credibility as being similar to the concept of internal validity. To ensure credibility, a range of data collection methods, known as data triangulation, is used (Stahl & King, 2017). For this study, I used audio recordings of the sessions, written notes with the date, time and length of observation detailed, took photographs, critically reflected, and used the indicators of creativity checklist. As I employed an action research method, I used the same data approach across all three cycles and my critical friend, being my main supervisor, used questioning to prompt further critical reflection of the data.

As defined by Gunawan (2015), transferability "is a form of external validity," (p.10) where the data and findings of a study can be transferred to other settings. Stahl and King (2017) discuss transferability through the use of rich and "thick descriptions" (p. 27). To ensure rich descriptions within my study, I went through the audio recordings after the sessions, transcribing what was said, in order to complete the indicators of creativity checklist. Also, within the findings, I used direct quotes from the children to ensure rich, thick descriptions. This allows readers the ability to consider the transferability of the study findings within their own settings.

Dependability is reliant on the researcher being honest and conveying trust (Stahl and King, 2017) to the readers. To guarantee dependability of my study, I have acknowledged my role and made clear my assumptions and biases, as well as writing in the first person.

Stahl and King (2017) state that confirmability is "getting as close to objective reality as qualitative research can get," (p. 28). By using many different methods within my study, I have attempted to ensure the accuracy of data and I have been clear and transparent throughout all stages of the research.

3.10 Ethical considerations

Before commencing this study, I obtained ethics clearance from Curtin University. In addition, the Ethical Code for Early Childhood Researchers, developed by Bertram et al. (2016), was used as a foundation for ethical research for this study. The then director of the Early Childhood Centre provided consent as well as the parents and guardians of the participating children before data collection began. Respect was given for younger children with verbal consent of their participation as well as the ability to withdraw from in the study at any time. The activities were available for all children in the same setting, and data not collected for those not involved in the research. In all research stages, to maintain anonymity of participants, children were given pseudonyms and photographs taken as a form of data collection did not have children's faces visible. Data remained confidential and stored on a locked device to ensure privacy. During the selection of participants, sensitivity to culture was shown and efforts made to eliminate bias. Measures were taken to avoid maltreatment or harm towards participants. Finally, copies of any reports or publications will be provided to the early childhood centre, parents, guardians and participants. Copies of the information letters and consent forms for both the Centre Director and parents are presented in Appendix D.

3.11 Summary

This chapter has set out to describe the research methodology employed in this study. It began by outlining the paradigm employed as well as the epistemological assumptions underpinning the study. From there, it detailed the methodological approach used, the context and participants involved, the methods of data collection and analysis, and the ethical considerations for the study. The next chapter presents the findings from the data.

Chapter 4. Findings

4.1 Introduction

The previous chapter presented an overview of the research, the paradigm and epistemological stance, and the methodological approach used for the study. It also presented the context and participants of the study, tools for data collection, data analysis and ethical considerations. This chapter now outlines the data findings.

The chapter commences with a brief overview of the three cycles of action. It then presents a summary of the indicators of creativity and the common themes identified for each child. This is followed by a cross case analysis of all six children, and discussion of the indicators from the ideation stage to the creation and reflection and evaluation stages, as well as the overarching social and emotional capabilities. Lastly, the chapter explores common themes across all six children, and the development of the educator's pedagogy and practice throughout the study.

4.2 Overview

In the first cycle of action, the participating children were observed in their play environment, interacting with the resources in the setting. Two observations were made with children playing in groups or pairs and the other four were of children's individual, solo play giving a total of six observations for this cycle. In the second cycle of action, the children were given a problem of getting Sally the doll to cross the water trough by making a boat. For cycle two, a total of seven learning stories were completed. The third and final cycle saw the children making a bridge for the Three Billy Goats Gruff to cross. A frequency of indicators table was developed for each child, adopted from the Indicators of Creativity Checklist in Appendix A and shows the indicators of creativity achieved in each cycle for each individual child. The following section now presents summaries of indicators and the emerging themes for each child, developed in conjunction with their learning stories. Due to the size of the learning stories, each full text is included in Appendix C at the end of this thesis.

4.3 Child One – Ava

Ava was observed four times, twice in cycle one and twice in cycle two. In observation one she worked with Adam and Sarah and in observations two, three and four she worked in a pair with Sarah. Ava left the centre and did not participate in cycle three. The following table shows the number of observations for Ava and how long each took.

Table 4.1 Observation Times for Ava

Observations	Cycle one Times	Cycle two Times	Cycle three Times
Observation 1 28th May 2019	3:45pm – 4:15pm 30 minutes	n/a	n/a
Observation 2 4th June 2019	1:50pm – 2:10pm 20 minutes	n/a	n/a
Observation 3 22nd October 2019	n/a	2:10pm – 2:55pm 45 minutes	n/a
Observation 4 19th November 2019	n/a	11:00am – 11:30am 30 minutes	n/a
Total Time to Complete Each Activity	30 minutes 20 minutes	1 hour, 15 minutes	

Time

Table 4.1 shows that Ava participated in cycles one and two but left the centre in cycle three. From cycle one to cycle two, Ava's time spent engaged either increased or remained the same. The third observation, which was part of cycle two, was the longest at 45-minutes. This represented an increase from both cycle one times of 30-minutes and 20-minutes. The fourth observation, which was also in cycle two was 30-minutes, the same as observation one, but an increase from observation two. During these observations, the Indicators of Creativity Checklist was used and each number in table 4.2 (below) indicates how many times Ava demonstrated the indicator. The percentage in brackets next to the number represents how often that indicator was demonstrated within that cycle.

Table 4.2 Summary of Indicators for Ava

Indicator	Cycle one f (%)	Cycle two f (%)	Cycle three f (%)
Ideation (I)			
I1 Asks Questions	0	0	n/a
I2 Challenges other ideas or assumptions	0	0	n/a
I3 Proposes multiple ideas for design	0	0	n/a
I4 Reflects critically on ideas	0	1(5%)	n/a
I5 Makes connections between things that are not usually connected	0	0	n/a
I6 Proposes and gives reasons for a possible solution	0	1(5%)	n/a
I7 Imagines multiple uses for an object	0	0	n/a
Creation (C)			
C1 Establishes a purpose for their actions	2(33.3%)	2(10%)	n/a
C2 Draws together two ideas or objects to propose something new	0	0	n/a
C3 Uses an object in a way other than its intended use	0	2(10%)	n/a
C4 Modifies initial design	0	1(5%)	n/a
C5 Tries out new arrangements or approaches	1(16.7%)	1(5%)	n/a
C6 Generates a solution to solve a problem	1(16.7%)	1(5%)	n/a
Reflection and Evaluation (RE)			
RE1 Reflects critically during the creating process	0	2(10%)	n/a
RE2 Reflects critically on idea and process for solving problem or constructing the product	0	1(5%)	n/a
RE3 Evaluates the product for its originality, effectiveness and being fit for purpose	0	2(10%)	n/a
Overarching Social and Emotional Capabilities			
SE1 Resilience: Staying with the task even when struggling and learning from previous errors	0	2(10%)	n/a
SE2 Self-Determination: intrinsically motivated to solve a problem or complete a task	1(16.7%)	2(10%)	n/a
SE3 Collaboration: Playing and learning collaboratively with peers	1(16.7%)	2(10%)	n/a
SE4 Uniqueness: Being prepared to be different	0	0	n/a
SE4 Openness: Being receptive to novel ideas, imagination and fantasy	0	0	n/a
Total Number of Indicators:	**6**	**20**	**n/a**

The following paragraphs discuss the emergent findings from Ava's summary of indicators from table 4.2 in conjunction with the data presented in the learning stories (Appendix C). This includes persistence, engagement, resilience, reflection and material use. Time was also a key theme, previously discussed in relation to table 4.1. The codes in the brackets relate specifically to the relevant learning story as presented in Appendix C.

Persistence

In Ava's second observation in cycle one with Sarah, the children created a train using Mobilo, a small manipulative construction toy (Appendix C, LS 1.4). This was Sarah's creation that she had asked Ava to help her create. The pieces were at times difficult for the children to put together and would occasionally come apart (LS 1.4). Ava was pushing the train and said, "I need help, no one's helping me," after the train continuously broke apart (LS 1.4). Ava believed it was because the train was too 'big.' After Sarah brought back a longer piece of Mobilo, Ava said she didn't want to participate anymore and decided to go and play elsewhere, demonstrating a lack of persistence. When I introduced the engineering design process in cycle two through the activity of creating a boat, Ava demonstrated an increase in persistence. Even though her boat sank in the first observation (LS 2.1), Ava returned to participate again in a second observation, creating a boat that could float whilst holding Sally the doll (LS 2.2). This contrasted from the observation in cycle one where she did not complete the activity to cycle two where she failed the task at first but returned to try again another day.

Engagement

In Ava's first observation with Adam and Sarah, she took the role of a follower in that, she did not contribute any ideas, repeating those of her peers, and followed along in the play (Appendix C, LS 1.3). In cycle two, Ava's engagement increased, she contributed more ideas such as making boats to get Sally across the river and shared her opinions, including that the boat was too short. She also created her own design of a boat and offered advice, including generating a solution to Sarah's problem of attaching the sail to the boat. There was also an increase in the amount of time spent on the activities from cycle one to cycle two. The train observation in cycle one lasted for 20 minutes, whereas the first observation in cycle two went for 45 minutes and the second observation went for 30 minutes. This demonstrated an increase in Ava's engagement as she participated in both cycle two observations for longer periods.

Resilience

Ava's increased engagement time from cycle one to cycle two also demonstrated an increase in her resilience to remain on task. She gave up easily after not being able to keep the Mobilo pieces together in in cycle one, but after her boat sank in cycle two, she was still determined to make a boat that would float and returned to participate again in the next session.

Reflection

Ava did not appear to show evidence of reflection in either of the two observations in cycle one. However, in cycle two, there was an increase in reflection through the Inquiry Questioning Model. I asked Ava a question after the trying out stage "Did it work Ava?" and she replied, "No." At the end of next observation, during the reflecting and reasoning stages, I asked questions to recap what happened during the activity. "Did you make your boat like your original design?" Ava said, "No." She was then asked, "How is it different to your original design?" Ava replied saying, "Because we attach it very big." I then asked why their original design didn't work. Ava said, "Because it wasn't big enough." Lastly, she was asked, "Did it work after you made the changes and made it bigger?" Ava replied, "Yeah." Through questioning, Ava was able to voice her reflections of the process of creating a boat that could float whilst holding Sally the doll.

Material Use

From cycle one to cycle two there was a distinct change in the types of materials Ava used. In cycle one Ava created using blocks, Mobilo and drawing, but in cycle two she used plastic containers and plastic straws for construction, using these objects in ways other than their intended use. Ava used the plastic container as the base of the boat and Slurpee straws as oars, as indicators of creativity. As per the Inquiry Questioning Model, I prepared the materials and the activity before implementing it with the children. In Ava's case, this proforma contributed to an increase in this creativity indicator.

4.4 Child Two – Sarah

Sarah participated in three observations for cycle one, one in a group of three, one in a pair and one individually. In cycle two, Sarah participated in two observations in a pair and in cycle three she again participated in one observation in a pair. The following table shows the number of observations for Sarah and how long each took.

Table 4.3 Observation Times for Sarah

Observations	Cycle one Times	Cycle two Times	Cycle three Times
Observation 1 twenty-first May 2019	1:45pm – 2:05pm 20 minutes	n/a	n/a
Observation 2 28th May 2019	3:45pm – 4:15pm 30 minutes	n/a	n/a
Observation 3 4th June 2019	1:50pm – 2:10pm 20 minutes	n/a	n/a
Observation 4 22nd October 2019	n/a	2:10pm – 2:55pm 45 minutes	n/a
Observation 5 19th November 2019	n/a	11:00am – 11:30am 30 minutes	n/a
Observation 6 10th December 2019	n/a	n/a	10:55am – 11:30am 35 minutes
Total Time to Complete Each Activity	20 minutes 30 minutes 20 minutes	1 hour, 15 minutes	35 minutes

Time

As shown in table 4.3, Sarah's session times increased from two 20-minute sessions and one 30-minute session in cycle one to a 45-minute session and 30-minute session in cycle two. As the two sessions in cycle two were to implement the design process, Sarah along with Ava took two sessions to successfully create a floating boat for Sally so adding the two session times together makes cycle two, one hour and 15 minutes long. In comparison to cycle one, it took a greater amount of time to complete the task of creating a finishing product. Cycle three however only took Sarah, together with William, 35 minutes to complete. By this stage, Sarah had already completed a design process and may have been comfortable with the process, but also the activity in cycle two proved to be more difficult than the activity in cycle three. Creating a boat that floats with a doll inside was more difficult to master than creating a bridge that could hold the weight of three goat figurines.

Each number in table 4.4 indicates how many times Sarah demonstrated the indicator. The percentage in brackets next to the number represents how often that indicator was demonstrated within that cycle.

Table 4.4 Summary of Indicators for Sarah

Indicators	**Cycle one f (%)**	**Cycle two f (%)**	**Cycle three f (%)**
Ideation (I)			
I1 Asks Questions	0	0	1 (6.7%)
I2 Challenges other ideas or assumptions	1(4.8%)	0	0
I3 Proposes multiple ideas for design	1(4.8%)	1(4.3%)	0
I4 Reflects critically on ideas	0	1(4.3%)	1(6.7%)
I5 Makes connections between things that are not usually connected	0	1(4.3%)	0
I6 Proposes and gives reasons for a possible solution	0	1(4.3%)	0
I7 Imagines multiple uses for an object	0	0	0
Creation (C)			
C1 Establishes a purpose for their actions	3(14.3%)	2(8.7%)	1(6.7%)
C2 Draws together two ideas or objects to propose something new	1(4.8%)	1(4.3%)	0
C3 Uses an object in a way other than its intended use	1(4.8%)	2(8.7%)	1(6.7%)
C4 Modifies initial design	1(4.8%)	2(8.7%)	1(6.7%)
C5 Tries out new arrangements or approaches	1(4.8%)	1(4.3%)	1(6.7%)
C6 Generates a solution to solve a problem	3(14.2%)	0	1(6.7%)
Reflection and Evaluation (RE)			
RE1 Reflects critically during the creating process	1(4.8%)	0	1(6.7%)
RE2 Reflects critically on idea and process for solving problem or constructing the product	0	1(4.3%)	1(6.7%)
RE3 Evaluates the product for its originality, effectiveness and being fit for purpose	0	2(8.7%)	1(6.7%)
Overarching Social and Emotional Capabilities			
SE1 Resilience: Staying with the task even when struggling and learning from previous errors	2(9.5%)	2(8.7%)	1(6.7%)
SE2 Self-Determination: intrinsically motivated to solve a problem or complete a task	3(14.2%)	2(8.7%)	1(6.7%)
SE3 Collaboration: Playing and learning collaboratively with peers	1(4.8%)	2(8.7%)	1(6.7%)
SE4 Uniqueness: Being prepared to be different	1(4.8%)	1(4.3%)	1(6.7%)
SE4 Openness: Being receptive to novel ideas, imagination and fantasy	1(4.8%)	1(4.3%)	1(6.7%)
Total Number of Indicators:	**21**	**23**	**15**

The following paragraphs discuss the emergent findings from Sarah's summary of indicators in table 4.4 and the data presented in the learning stories (Appendix C). Both reflection and time were key themes, previously discussed in relation to table 4.3.

Reflection

It is evident in the data that there was an increase in Sarah's reflective capacity after implementing the engineering design process inquiry questioning framework over the three cycles. During cycle one, Sarah did not verbally reflect on her ideas at any stage. However, Sarah must have reflected internally when she changed her mind about the "spots" she was creating using playdough. Sarah's peer used all the sticks provided, so Sarah said, "We don't need candles." Later in the session, after Sarah had started making her "spots" she said, "I've got to make lots of spots. I'm making circles." When asked what the spots were for, she replied, "For the candles." This change demonstrated that Sarah had reflected on how she could make candles for her cake without using sticks as they had all been used by her peer. In cycle two, Sarah created a boat for Sally the doll with Ava. After testing out their first boat, Sarah and Ava answered the reflective questions about whether the boat worked and what they could do to be successful. Sarah said, "I Think we need to make it bigger," in relation to how they could solve the problem of Sally's boat sinking.

The next session involved the participants improving their design. Ava suggested creating a heavier boat. At first, Sarah thought that a heavier boat would float, but after some internal reflection she changed her mind and decided it would sink. After creating the boat and finding it to be successful, Sarah answered two of my questions, as follows:

> Me: Did you make your boat like your original design?
> Sarah: No.
> Me: Did it work after you made the changes and made it bigger?
> Sarah: Yeah

Sarah teamed up with William in cycle three to create the bridge for the Three Billy Goats Gruff. Sarah drew her design of the bridge but only drew the top part, not what would hold it up. She reflected on her ideas as follows:

> Me: Sarah, I know you've done where they will walk, but how will the bridge stand, because are bridges flat on the water or is there a bit of space?
> Sarah and William: A bit of space.
> *I asked Sarah what she needed to put underneath*

Sarah: Water
The question was rephrased
Me: And then how will your bridge here stand?
I pointed to the ends.
Sarah: It's going to stand in the water.
Then when Sarah asked William about his bridge.
William: But where are the legs that can stand?
Sarah reflected and understood that she needed to have "legs" or stands under her bridge to hold it up over the water and decided to use plastic cups to do this.

With some prompting Sarah created the walkway for her bridge. She had some straws and said she needed a lot of them to make her bridge look "interesting."

Me: What would happen if we attach lots and lots of these together?
Sarah: What if we attach them all together?
Me: Do you think that would be strong enough for the billy goats to walk over?
Sarah: Yeah, that would.

After reflecting about using straws, Sarah was able to create the walkway for her bridge and when she tested it out, it was strong enough to hold the weight of the three Billy Goats Gruff. Sarah reflected after creating her bridge as follows:

Me: Do you need to change anything?
Sarah: No.
William interjected saying that they did need to change the cups which were to be used as stands to keep the bridge up and over the water.
Me: The cups. That's what you did change wasn't it, so it was different from your first drawing wasn't it, Sarah?
Sarah: Yeah
Me: How is it different?
Sarah: The long stem
Me: The legs? How did you make the legs instead?
Sarah: I just put these on *[Referring to the bigger plastic cups.]*
Me: You just used the big cups.

With reflection being a key indicator of children's creativity, intentionally introducing an engineering design process and an inquiry questioning framework allowed Sarah to reflect during the ideation process, whilst creating, and on the finished product. This was not something verbalised or demonstrated as often in cycle one.

4.5 Child Three – Adam

Adam was observed once in cycle one with Ava and Sarah. He partnered with James for cycle two where he was observed three times. In cycle three he was observed once working with James and Olivia. The following table shows the number of observations for Adam and how long each took.

Table 4.5 Observation Times for Adam

Observations	Cycle one Times	Cycle two Times	Cycle three Times
Observation 1 28th May 2019	3:45pm – 4:15pm 30 minutes	n/a	n/a
Observation 2 24th October 2019	n/a	11:20am – 12:20pm 60 minutes	n/a
Observation 3 14th November 2019	n/a	11:05am – 11:40am 35 minutes	n/a
Observation 4 5th December 2019	n/a	11:00am – 11:30am 30 minutes	n/a
Observation 5 12th December 2019	n/a	n/a 14 minutes	n/a
Observation 6 12th December 2019	n/a	n/a	4:00pm – 4:25pm 25 minutes
Total Time to Complete Each Activity	30 minutes	2 hours, 19 minutes	25 minutes

Time

As shown in table 4.5, the time Adam spent engaged with the activities increased from cycle one to cycle two but decreased in cycle three. His cycle one observation was 30 minutes long. Cycle two however, took four attempts with a 60-minute, 35-minute, 30-minute and a 15-minute session. Cycle three was 25 minutes, a decrease from cycles one and two. This decrease in time could be due to the activity in cycle three being less difficult than the activity in cycle two or Adam and his peer's greater familiarity with the design process after completing cycle two. However, there was still a five-minute decrease in time from cycle one to cycle three with both Adam's observation with Ava and Sarah, and James' observation having the longest cycle one times of 30 minutes.

Each number in table 4.6 indicates how many times Adam demonstrated the indicator. The percentage in brackets next to the number is how often that indicator was demonstrated within that cycle.

Table 4.6 Summary of Indicators for Adam

Indicators	Cycle one f (%)	Cycle two f (%)	Cycle three f (%)
Ideation (I)			
I1 Asks Questions	0	1(3.8%)	1(10%)
I2 Challenges other ideas or assumptions	0	1(3.8%)	1(10%)
I3 Proposes multiple ideas for design	1(10%)	1(3.8%)	1 (10%)
I4 Reflects critically on ideas	0	1(3.8%)	1(10%)
I5 Makes connections between things that are not usually connected	0	0	0
I6 Proposes and gives reasons for a possible solution	0	1(3.8)	0
I7 Imagines multiple uses for an object	0	0	0
Creation (C)			
C1 Establishes a purpose for their actions	1(10%)	4(15.4%)	1(10%)
C2 Draws together two ideas or objects to propose something new	0	0	0
C3 Uses an object in a way other than its intended use	0	2(7.7%)	1(10%)
C4 Modifies initial design	1(10%)	3(11.5%)	0
C5 Tries out new arrangements or approaches	1(10%)	2(7.7%)	0
C6 Generates a solution to solve a problem	1(10%)	1(3.8%)	0
Reflection and Evaluation (RE)			
RE1 Reflects critically during the creating process	1(10%)	1(3.8%)	1(10%)
RE2 Reflects critically on idea and process for solving problem or constructing the product	0	0	0
RE3 Evaluates the product for its originality, effectiveness and being fit for purpose	0	1(3.8%)	1(10%)
Overarching Social and Emotional Capabilities			
SE1 Resilience: Staying with the task even when struggling and learning from previous errors	1(10%)	2(7.7%)	0
SE2 Self-Determination: intrinsically motivated to solve a problem or complete a task	1(10%)	2(7.7%)	1(10%)
SE3 Collaboration: Playing and learning collaboratively with peers	1(10%)	2(7.7%)	1(10%)
SE4 Uniqueness: Being prepared to be different	0	0	0
SE4 Openness: Being receptive to novel ideas, imagination and fantasy	1(10%)	1(3.8%)	0
Total Number of Indicators:	**10**	**26**	**10**

The following discusses the emergent findings from Adam's summary of indicators table and the data presented in the learning stories (Appendix C). This included resilience, reflection, questioning and material use. Time was also a key theme, as discussed in relation to table 4.5.

Resilience

In cycle two, Adam demonstrated resilience when he was observed four times helping James create a boat that would float even after it sank multiple times. It was evident in the learning stories that his continued participation demonstrated resilience despite the boat continuously sinking. His resilience paid off in the fourth observation in cycle two when he and James successfully modified their design to create a boat that floated with Sally inside.

Reflection

Adam's reflective ability increased in cycle two and cycle three, compared to cycle one. As in the above frequency of indicators table, Adam only reflected once in cycle one, during the creating process. In cycle two and three he continued to reflect during the creating process, but also evaluated the product after successfully creating a floating boat with James and a bridge with James and Olivia as follows:

> Me: What happened that time when we tested the boat?
> Adam: It sank
> Me: Did it?
> James: No
> Adam: It floated
> Me: Was it the same as the original drawings we did
> James: No
> Me: How did we make it different, what did we change?
> Adam: It was, but this part was like this
> *Adam pointing to one rectangle of the boat.*
> Me: Yep, that's right so the rectangle piece, there was one rectangle piece that was like that, that was yours Adam. But when we did the one rectangle piece did it float or did it sink?"
> Adam and James: Sink
> Me: So, then what did we do?
> Adam: And then we just, we did…
> *Adam pointing to the other piece of the boat.*
> Me: We did another one, we got another piece and stuck it together. And then what happened when we put Sally in the boat and tested it out?
> Adam and James: It sunk
> Me: So, then James came up with an idea, that we could put?"
> James: Water in a bottle

Questioning

Adam asked questions in both cycles two and three. He was one of two participants who asked questions throughout the study and the most compared to the other participants. In cycle two, Adam asked how sticky tape was made and what it is made from. He also asked about using "electric glue," the term he used for a glue gun. In cycle three, Adam asked about the durability of a particular resource during the creating process, "Is masking tape strong? Stronger than the light tape?" When I asked, "What do you think?" Adam responded to his own question alongside his peers with, "Stronger." Asking questions is an indicator of creativity which Adam demonstrated with only one other participant asking a question in cycle three.

Material Use

Adam used the materials in ways other than their intended use in cycles two and three. In cycle one, Adam created a tower with blocks and a satellite using Mobilo, both materials that are designed for building. In cycle two, he helped to create boats using plastic containers, Styrofoam and a water bottle, and lastly in cycle three he helped to make a bridge using straws and plastic cups. In cycle one, I asked Adam and his peers what they could make. Adam had a few suggestions including a mirror, a cat and a dog but then settled with making a tower. When asked how to make the tower, Adam replied saying, "We start with blocks." After building his tower, Adam then talks about satellites and made one using Mobilo. In cycle two, I had intentionally prepared materials prior to the activity that would generate discussions around the use of certain materials in water. In cycle three I also prepared materials to create a bridge. This preparation contributed to Adam using the materials in ways other than their intended use. Rather than using the standard building materials on offer, Adam used materials he may not have been inclined to use through the intentional inclusion of the design process.

4.6 Child Four – Olivia

Olivia was observed three times, once for each cycle. She worked individually in cycles one and two, and in collaboration with Adam and James in cycle three. The following table shows the number of observations for Olivia and how long each took.

Table 4.7 Observation Times for Olivia

Observations	Cycle one Times	Cycle two Times	Cycle three Times
Observation 1 7th August 2019	10:45 am – 10:52am 7 minutes	n/a	n/a
Observation 2 11th December 2019	n/a	10:15am – 11:00am 45 minutes	n/a
Observation 3 12th December 2019	n/a	n/a	4:00pm – 4:24pm 25 minutes
Total Time to Complete Each Activity	7 minutes	45 minutes	25 minutes

Time

As shown in table 4.7, there was a significant increase in time spent on activities from cycle one to cycle two, with cycle one being seven minutes and cycle two being 45 minutes. Olivia's time of engagement for cycle three was 25 minutes with her peers James and Adam, less than cycle two but still a considerably longer than cycle one. In cycle one, Olivia created a house with a garage using Duplo. After creating her house, I asked Olivia, "Does your house or car need anything else or is it finished now?" Olivia replied saying, "It's finished now." Olivia did not show any motivation to continue creating. In cycle two, Olivia's engagement increased, and she showed more enthusiasm, telling me stories about boats, and discussing different materials and what would happen if they got wet. This extra discussion and time in cycle two demonstrated that Olivia was more engaged than in cycle one. The activity in cycle three was not as complex as cycle two which led to a shorter time period from cycle two to cycle three. However, the length of time in cycle three was 18 minutes more than the time spent in cycle one.

In table 4.8, each number indicates how many times Olivia demonstrated the indicator. The percentage in brackets next to the number represents how often that indicator was demonstrated within that cycle.

Table 4.8 Summary of Indicators for Olivia

Indicators	**Cycle one f (%)**	**Cycle two f (%)**	**Cycle three f (%)**
Ideation (I)			
I1 Asks Questions	0	0	0
I2 Challenges other ideas or assumptions	0	0	0
I3 Proposes multiple ideas for design	0	1(7.1%)	0
I4 Reflects critically on ideas	0	1(7.1%)	1(10%)
I5 Makes connections between things that are not usually connected	0	1(7.1%)	0
I6 Proposes and gives reasons for a possible solution	0	1(7.1%)	1(10%)
I7 Imagines multiple uses for an object	0	0	0
Creation (C)			
C1 Establishes a purpose for their actions	1(25%)	1(7.1%)	1(10%)
C2 Draws together two ideas or objects to propose something new	0	0	0
C3 Uses an object in a way other than its intended use	0	1(7.1%)	1(10%)
C4 Modifies initial design	0	0	0
C5 Tries out new arrangements or approaches	1(25%)	1(7.1%)	0
C6 Generates a solution to solve a problem	1(25%)	1(7.1%)	1(10%)
Reflection and Evaluation (RE)			
RE1 Reflects critically during the creating process	0	1(7.1%)	1(10%)
RE2 Reflects critically on idea and process for solving problem or constructing the product	0	1(7.1%)	1(10%)
RE3 Evaluates the product for its originality, effectiveness and being fit for purpose	0	1(7.1%)	1(10%)
Overarching Social and Emotional Capabilities			
SE1 Resilience: Staying with the task even when struggling and learning from previous errors	0	1(7.1%)	0
SE2 Self-Determination: intrinsically motivated to solve a problem or complete a task	1(25%)	1(7.1%)	1(10%)
SE3 Collaboration: Playing and learning collaboratively with peers	0	0	1(10%)
SE4 Uniqueness: Being prepared to be different	0	0	0
SE4 Openness: Being receptive to novel ideas, imagination and fantasy	0	1(7.1%)	0
Total Number of Indicators:	**4**	**14**	**10**

The following discusses the emergent findings from Olivia's summary of indicators from table 4.8 and the data presented in the learning stories (Appendix C). Findings include perseverance, autonomy and material use. Time was also a key theme, previously discussed in relation to table 4.7.

Perseverance

In cycle two, Olivia demonstrated perseverance. After her first attempt at testing out her boat failed, I asked, “What do you think would make your boat float? What could make it better?” Olivia replied saying, “Maybe put a bit more water in or a bit less,” She was then asked, “What do you think? More or less water? Because it made it sink, didn’t it?” Olivia replied saying, “Less.” She realised the bottle of water she had in the boat to evenly distribute Sally’s weight was too heavy and she needed to tip some water out. Olivia tried again but her boat again sank. She then tipped out more water until there was only a small amount left and on her third attempt, she was successful in making her boat float. This was not demonstrated in cycles one or three. In cycle one, the roof of Olivia’s garage collapsed, and she needed to fix it but it did not require anything extensive and did not seem to bother her as she placed a couple of Duplo blocks onto the roof without expression, only saying “oops” and “there we go” after fixing her building.

Autonomy

Throughout all the cycles Olivia displayed autonomous behaviour. This was apparent in cycle three where she collaborated with Adam and James. When asked, “What are we going to make the top of the bridge from?” Olivia replied saying, “These,” whilst picking up a pop stick. She persisted with this even when Adam suggested using paper. I asked “Do you think that would hold the Three Billy Goats Gruff? Do you think that would be strong enough?” referring to the idea of using paper to make the top of the bridge. “No, it will rip,” said James. “But these will be strong enough,” said Olivia referring to the pop sticks. Olivia also suggested using sticky tape to stick the pop sticks together and place them side by side to create the top of the bridge. Adam and James then helped Olivia to place the sticky tape on the pop sticks without them moving.

Material Use

Like Adam, in cycles two and three, Olivia used the materials in different ways to their intended use. As noted in her learning story, Olivia used a plastic container as the base of her boat, a juice bottle as a weight and a straw and paper as a sail for her boat. In cycle three, Olivia suggested using pop sticks to make the walkway of the bridge, but in cycle one, Olivia used the Duplo Lego in the way it is intended, for building.

4.7 Child Five – James

James was observed once individually in cycle one. In cycle two, he was observed five times working with Adam as well as individually for observation five. In cycle three, James worked alongside Adam and Olivia in one observation. The following table shows the number of observations for James and how long each took.

Table 4.9 Observation Times for James

Observations	Cycle one Times	Cycle two Times	Cycle three Times
Observation 1 24th May 2019	10:50am – 11:20am 30 minutes	n/a	n/a
Observation 2 24th October 2019	n/a	11:20am – 12:20pm 60 minutes	n/a
Observation 3 14th November 2019	n/a	11:05am – 11:40am 35 minutes	n/a
Observation 4 5th December 2019	n/a	11:00am – 11:30am 30 minutes	n/a
Observation 5 5th December 2019	n/a	2:25pm – 2:41pm 16 minutes	n/a
Observation 6 12th December 2019	n/a	n/a 14 minutes	n/a
Observation 7 12th December 2019	n/a	n/a	4:00pm – 4:24pm 25 minutes
Total Time to Complete Each Activity	30 minutes	2 hours, 35 minutes	25 minutes

Time

As shown in table 4.9, the time James spent engaged with the activities increased from cycle one to cycle two but decreased in cycle three. His times were the same as Adam. His cycle one observation was 30 minutes long while cycle two took five attempts with 60 minute, 35 minute, 30 minute, 15 minute and 14 minute sessions. Cycle three however, was 25 minutes, a decrease in time from cycles one and two. As for the others, this decrease could be due to the activity being less difficult than in cycle two or that James and his peers being more familiar with the design process after completing cycle two, As noted in Adam's findings, James and Adam's observation with Ava and Sarah both had the longest cycle one times.

In table 4.10, each number indicates the number of times James demonstrated the indicator. The percentage in brackets next to the number represents how often that indicator was demonstrated within that cycle.

Table 4.10 Summary of Indicators for James

Indicators	Cycle one f (%)	Cycle two f (%)	Cycle three f (%)
Ideation (I)			
I1 Asks Questions	0	0	0
I2 Challenges other ideas or assumptions	0	0	0
I3 Proposes multiple ideas for design	0	2(5.6%)	0
I4 Reflects critically on ideas	0	1(2.8%)	1(11.1%)
I5 Makes connections between things that are not usually connected	0	0	0
I6 Proposes and gives reasons for a possible solution	0	1(2.8%)	0
I7 Imagines multiple uses for an object	0	0	1(11.1%)
Creation (C)			
C1 Establishes a purpose for their actions	1(16.7%)	4(11.1%)	1(11.1%)
C2 Draws together two ideas or objects to propose something new	0	1(2.8%)	0
C3 Uses an object in a way other than its intended use	1(16.7%)	3(8.3%)	1(11.1%)
C4 Modifies initial design	1(16.7%)	3(8.3%)	0
C5 Tries out new arrangements or approaches	1(16.7%)	4(11.1%)	0
C6 Generates a solution to solve a problem	1(16.7%)	3(8.3%)	0
Reflection and Evaluation (RE)			
RE1 Reflects critically during the creating process	0	2(5.6%)	1(11.1%)
RE2 Reflects critically on idea and process for solving problem or constructing the product	0	2(5.6%)	1(11.1%)
RE3 Evaluates the product for its originality, effectiveness and being fit for purpose	0	1(2.8%)	1(11.1%)
Overarching Social and Emotional Capabilities			
SE1 Resilience: Staying with the task even when struggling and learning from previous errors	0	2(5.6%)	0
SE2 Self-Determination: intrinsically motivated to solve a problem or complete a task	1(16.7%)	3(8.3%)	1(11.1%)
SE3 Collaboration: Playing and learning collaboratively with peers	0	2(5.6%)	1(11.1%)
SE4 Uniqueness: Being prepared to be different	0	1(2.8%)	0
SE4 Openness: Being receptive to novel ideas, imagination and fantasy	0	1(2.8%)	0
Total Number of Indicators:	**6**	**36**	**9**

The following discusses the emergent findings from table 4.10, James' summary of indicators and the data presented in the learning stories (Appendix C) and includes reflection and resilience. Time was also a key theme, previously discussed in relation to table 4.9.

Reflection

It can be seen in table 4.10 that James did not demonstrate any indicators of reflection in cycle one, while reflections increased for cycle two and dropped for cycle three. However, when looking at the percentage of indicators, there was an increase from 6% during the creating process and the idea and process for solving problem or constructing the product in cycle two to 11% in cycle three. Further, even though there were the same number of indicators for cycles two and three when it came to evaluating the product, the percentage of indicators for cycle two was 3% compared to 11% for cycle three. The increase in reflection from cycle one to cycles two and three suggests the potential of the inquiry questioning process and the prepared questions on James demonstrating ability to reflect, as follows:

> Me: We tipped some water out today and then we tested it again, but it sunk and it fell which side did it fall from? The left side, the right side or the middle?
> James: The middle.
> Me: So, what did we need to do?
> James: We needed to put it there.
> *James pointed to the left side.*
> Me: You needed to move the bottle onto the left side. So, why didn't the first work?
> James: Because the bottle was full.
> Me : Because it was too?
> James: Heavy.
> Me: And it was in the wrong?
> Adam: Place.
> Me: So, we had to even it out, didn't we? Put Sally on one side and the bottle on the other side, so it would go?
> James: Flat.

In cycle three, Adam asked a question during the creating process with James replying as follows:

> Adam: Is masking tape strong? Stronger than the light tape?
> Me: What do you think?
> James: Stronger

Further, whilst creating, I asked the children how they could attach the walkway of the bridge to the plastic cup stands they were going to use. James replied, "Masking tape, because masking tape's the strongest."

Resilience

James and Adam took four attempts to make a boat that would float with Sally inside. This indicated resilience to continue with the activity after initially failing. James did not have the opportunity to display the same resilience in cycle one where he made a collage of a bus or in cycle three, as these activities only took one attempt.

4.8 Child Six – William

William was observed three times, once for each cycle. He worked individually in cycles one and two and in collaboration with Sarah in cycle three. The following table shows the number of observations for William and how long each took.

Table 4.11 Observation Times for William

Observations	Cycle one Times	Cycle two Times	Cycle three Times
Observation 1 29th October 2019	3:00pm – 3:25pm 25 minutes	n/a	n/a
Observation 2 3rd December 2019	n/a	11:00am – 11:30am 30 minutes	n/a
Observation 3 10th December 2019	n/a	n/a	10:55am – 11:30am 35 minutes
Total Time to Complete Each Activity	25 minutes	30 minutes	35 minutes

Time

As shown in table 4.11, the time spent on the activities increased by five minutes for each cycle. William went from 25 minutes in cycle one to 30 minutes in cycle two and 35 minutes in cycle three. This increase in time also demonstrated an increase in engagement. In cycle one, William took 12 minutes to create a dinosaur using blocks. To try and extend on this activity and time, I prompted William to create more by saying, "Maybe we can make dinosaurs out of something else." William did not reply so I then asked, "Do you think maybe we could make dinosaurs out of the Mobilo or Duplo?" to which William replied, "Mmmm… Lego!" If I had not prompted William with a choice between Mobilo or Duplo, the session would have ended sooner. However, William then chose Lego Duplo and went on to create another dinosaur which then made the session 25 minutes long.

In table 4.12, each number indicates the number of times William demonstrated the indicator. The percentage in brackets next to the number represents how often that indicator was demonstrated within that cycle.

Table 4.12 Summary of Indicators for William

Indicators	Cycle one f (%)	Cycle two f (%)	Cycle three f (%)
Ideation (I)			
I1 Asks Questions	0	0	0
I2 Challenges other ideas or assumptions	0	0	1(6.2%)
I3 Proposes multiple ideas for design	0	1(7.7%)	0
I4 Reflects critically on ideas	0	1(7.7%)	1(6.2%)
I5 Makes connections between things that are not usually connected	0	0	0
I6 Proposes and gives reasons for a possible solution	0	1(7.7)	1(6.2%)
I7 Imagines multiple uses for an object	0	0	0
Creation (C)			
C1 Establishes a purpose for their actions	1(20%)	1(7.7%)	1(6.2%)
C2 Draws together two ideas or objects to propose something new	0	0	0
C3 Uses an object in a way other than its intended use	0	1(7.7%)	1(6.2%)
C4 Modifies initial design	1(20%)	1(7.7%)	1(6.2%)
C5 Tries out new arrangements or approaches	1(20%)	1(7.7%)	1(6.2%)
C6 Generates a solution to solve a problem	0	1(7.7%)	1(6.2%)
Reflection and Evaluation (RE)			
RE1 Reflects critically during the creating process	0	1(7.7%)	1(6.2%)
RE2 Reflects critically on idea and process for solving problem or constructing the product	0	1(7.7%)	1(6.2%)
RE3 Evaluates the product for its originality, effectiveness and being fit for purpose	0	1(7.7%)	1(6.2%)
Overarching Social and Emotional Capabilities			
SE1 Resilience: Staying with the task even when struggling and learning from previous errors	0	1(7.7%)	1(6.2%)
SE2 Self-Determination: intrinsically motivated to solve a problem or complete a task	1(20%)	1(7.7%)	1(6.2%)
SE3 Collaboration: Playing and learning collaboratively with peers	0	0	1(6.2%)
SE4 Uniqueness: Being prepared to be different	0	0	1(6.2%)
SE4 Openness: Being receptive to novel ideas, imagination and fantasy	1(20%)	0	1(6.2%)
Total Number of Indicators:	**5**	**13**	**16**

The following discusses the emergent findings from William's summary of indicators and the data presented in the learning stories (Appendix C), and includes findings relating to reflection, challenging assumptions and material use. Time was also a key theme, previously discussed in relation to table 4.11.

Reflection

William demonstrated an increase in reflection from cycle one to cycles two and three as promoted by the inquiry questioning design process. After William created his boat, tested it out and found that it successfully floated, I asked him some reflective questions illustrated in the following dialogue.

> Me: What happened to the second boat we made?
> William: It sunk and float.
> Me: What happened when we put Sally on the very left side of the boat William:
> William: Umm it sunk.

> Me: And then what happened when we put Sally on the very right side of the boat?
> William: It sunk.
> Me: But what happened when we put Sally in the very middle of the boat?
> William: It didn't sink!
> Me: Did you make your boat the same as your initial design?
> William: No.
> Me: How is it different?
> William: Because it wasn't a square… rectangle.
> Me: When you made your rectangle, you put another container on the end, didn't you? What happened to that container?"
> William: It broke.
> Me: But did we need to have the other container on there?
> William: No, because it can go on its own.

Through the questioning, William was able to reflect on the process of testing out his boat.

Challenging Assumptions

In cycle three, William challenged Sarah's assumption that bridges cannot move. He said he had seen bridges move before whereas Sarah said they cannot. This conversation is transcribed in the learning stories. William did not demonstrate this in cycle one or two where he did not have a peer to engage with and challenge. This lack of collaboration was due to his late start in the study after another participant left. The peer collaboration in cycle three accounted for the increase of indicators of creativity as seen in the frequency of indicators checklist and evidence in the learning stories.

Material Use

The use of materials from cycle one to cycles two and three changed. William went from using wooden blocks and Duplo, using them for their intended use, to creating a boat with plastic containers and a bridge using straws and plastic containers, objects not usually used in this way, potentially reinforcing the value of the Inquiry Questioning proforma and the preparation done before the activity was undertaken.

4.9 Summary of Individual Children

So far, this chapter has presented an overview of the research, as well as the individual children's findings with tables containing the frequency of indicators of creativity created for each child. For Ava, time, persistence, engagement, resilience, reflection and creative use of materials emerged as key themes after the implementation of the Inquiry Questioning Model. For Sarah, time and reflection emerged, while for Adam, time, resilience, reflection, questioning and material use emerged. Olivia's findings indicated time, perseverance, autonomy and material use as key themes while for James, time, reflection and resilience emerged. Finally, for William, time, reflection, challenging assumptions, and material use emerged. Overall, the most common behaviours to emerge across all three cycles were time, reflection, material use, and resilience. The following section now presents the children's findings as a cross case comparison, exploring the key indicators for all children within each stage of the engineering design process and the overarching social and emotional capabilities. It then explores the key themes observed from the children as a group.

4.10 Cross Case Analysis

Table 4.13 presents a comparison of the indicators of creativity among all children in the study for each cycle. The following sections detail the key findings from this cross case comparison. As with the individual children's indicators of creativity checklist, the table also includes a percentage in brackets next to the number indicator within that cycle.

Table 4.13 Cross Case Comparison of Indicators of Creativity

Indicators	Cycle one f (%)	Cycle two f (%)	Cycle three f (%)
Ideation (I)			
I1 Asks Questions	0	1(0.7%)	2(3.3%)
I2 Challenges other ideas or assumptions	1(1.9%)	1(0.7%)	2(3.3%)
I3 Proposes multiple ideas for design	2(3.8%)	6(4.5%)	1(1.7%)
I4 Reflects critically on ideas	0	6(4.5%)	5(8.3%)
I5 Makes connections between things that are not usually connected	0	2(1.5%)	0
I6 Proposes and gives reasons for a possible solution	0	6(4.5%)	2(3.3%)
I7 Imagines multiple uses for an object	0	0	1(1.7%)
Creation (C)			
C1 Establishes a purpose for their actions	9(17.3%)	14(10.6%)	5(8.3%)
C2 Draws together two ideas or objects to propose something new	1(1.9%)	2(1.5%)	0
C3 Uses an object in a way other than its intended use	2(3.8%)	11(8.3%)	5(8.3%)
C4 Modifies initial design	4(7.7%)	10(7.6%)	2(3.3%)
C5 Tries out new arrangements or approaches	6(11.5%)	10(7.6%)	2(3.3%)
C6 Generates a solution to solve a problem	7(13.5%)	7(5.3%)	3(5%)
Reflection and Evaluation (RE)			
RE1 Reflects critically during the creating process	2(3.8%)	7(5.3%)	5(8.3%)
RE2 Reflects critically on idea and process for solving problem or constructing the product	0	6(4.5%)	4(6.7%)
RE3 Evaluates the product for its originality, effectiveness and being fit for purpose	0	8(6.1%)	5(8.3%)
Overarching Social and Emotional Capabilities			
SE1 Resilience: Staying with the task even when struggling and learning from previous errors	3(5.8%)	10(7.6%)	2(3.3%)
SE2 Self-Determination: intrinsically motivated to solve a problem or complete a task	8(15.4%)	11(8.3%)	5(8.3%)
SE3 Collaboration: Playing and learning collaboratively with peers	3(5.8%)	8(6.1%)	5(8.3%)
SE4 Uniqueness: Being prepared to be different	1(1.9%)	2(1.5%)	2(3.3%)
SE4 Openness: Being receptive to novel ideas, imagination and fantasy	3(5.8%)	4(3%)	2(3.3%)
Total Number of Indicators:	**52**	**132**	**60**

The key finding from the cross case analysis of creativity indicated an increase of indicators of creativity from cycle one to cycles two and three. This is discussed further in general terms for each stage of the design and the Overarching Social and Emotional Capabilities and in more detail for significant individual themes.

Ideation (I)

There was an increase during the ideation stage from cycle one to cycles two and three, however from cycle two to cycle three, indicators I3, I4, I5 and I6 decreased (shown in Table 4.13). There was limited opportunity to demonstrate indicators in the cycle one's ideation stage as most of the children worked independently, internalised their ideas and did not draw their designs. The number of sessions from cycle two to cycle three also contributed to the decrease in indicators as there were more sessions in cycle two than in cycle three.

The *Challenges indicator* (I2) remained the same from cycle one to cycle two with one indicator but increased from cycle two to three with two indicators. William demonstrated this in cycle three (see Appendix LS3.1) where Sarah told him that bridges do not move but William challenged this idea. This is evident in the following dialogue:

> William: I'm going to draw some paddles
> Me: What are the paddles for?
> William: To make the bridge go. 'Cause I've seen some bridge move before
> Me: Yeah, some bridges do move
> Sarah: No, they don't
> Me: There are some bridges that come up and go down
> *I lever my hand like a drawing string bridge going up and down*.
> William: Yeah, that's what I'm doing, up, down.

There was a more significant increase for the *Proposes/design indicator* (I3) from two indicators in cycle one to six indicators in cycle two. However, there was a decrease from cycle two to cycle three from six indicators to one. The task in cycle two allowed for more design ideas as there are many different types of boats that could be created in alternate ways, opposed to making a bridge.

The *Proposes/solution indicator* (I6) increased from cycle one to two with no indicators to six in cycle two. It then decreased from cycle two to cycle three with two indicators in cycle three. With the introduction of the Inquiry Questioning Model, the children had a problem they needed to solve in cycles two and three. All the children offered ideas to solve the problems in cycle two with Ava, James and Olivia suggesting a boat, Sarah said Sally "could go around" the river, Adam's idea was to use a trampoline so Sally could jump over the river, and William first suggested a bridge before deciding on creating a boat. In cycle three, only William and Olivia made suggestions to make a bridge.

Creation (C)

There was an increase in indicators for cycle one for the creation stage of the design process as opposed to the ideation stage as all children made objects in cycle one. All indicators in the creation stage increased from cycle one to cycle two except for the *Generates/solution indicator* (C6), which remained the same. In cycle three, findings indicated a decrease of indicators from cycle one and two except for the *Alternative uses indicator* (C3) which increased from cycle one to cycle three, but decreased from cycle two to cycle three. This decrease could be due to the nature of the activity in cycle three being less complicated than in cycle two because there were only two observations in cycle three opposed to six in cycle one and eight in cycle two.

After implementing the engineering design process, the *Alternative uses indicator* (C3) increased from two indicators in cycle one, 11 indicators in cycle two and five indicators in cycle three. In cycle one, the children chose to use resources designed for building like Duplo Lego, Mobilo and wooden blocks. Only Sarah used playdough for creating a cake and candles, and James drew a bus and then used scrap material. In cycle two and three, I set up a provocation using different recycled material such as a variety of plastic containers in different sizes, straws, cardboard, popsticks and Styrofoam pieces. The inclusion of a provocation and the recycled materials allowed the children to use these objects in different ways than their original purpose, and children demonstrated that they could use the materials for their creations.

The *Modifies initial design indicator* (C4) increased from cycle one with four indicators to cycle two with ten indicators. However, there was a decrease in cycle three with two indicators being demonstrated. The *Tries out new arrangements indicator* (C5) produced similar results as C4, but with six indicators in cycle one, and the same number of indicators in cycle two and three. In cycle one, the children did not draw their designs, but Sarah, Adam, James, and William did make changes when they faced a problem; both modified their initial design and tried out arrangements or approaches. As evidenced in Appendix C, Sarah (LS1.4) changed her train from being connected to just pushing it from the back as it kept coming apart while Adam (LS1.3) created a single column tower with wooden blocks but when it fell, he added another column for support. James, (LS1.2) wanted to draw with black Texta over black material and when he realised this would not work, he found some grey fabric to cut out and glue over the top instead. Lastly, William (LS1.6) created a dinosaur using blocks and when he decided he wanted it to be a tyrannosaurus rex, he changed out the blocks on its back and made the arms smaller with small cylinder blocks. In cycle two, the majority of the children found their design did not work the first time. They had to reflect and modify their initial designs to make them float. This activity involved more trial and error than cycle three, so the children were more successful creating the bridge after making it the first time.

Reflection and Evaluation (RE)

The critical reflection *Creating indicator* (RE1) was the only indicator demonstrated in cycle one with both Sarah and Adam demonstrating reflection during the creating process. The indicators increased in cycle two but decreased from cycle two to cycle three, however there was still an overall increase in indicators from cycle one to cycle three. All children demonstrated the *Critical reflection ideas indicator* (RE2) in cycles two and three except Adam. The children did not demonstrate the *Evaluation indicator* (RE3) in cycle one. However, after the implementation of the design process in cycle two and three, all children demonstrated this indicator, evaluating their designs through the questions I asked after testing out their creations.

The Inquiry Questioning Model (Murcia et al., 2020a) allowed for the reflection and evaluation indicators to be demonstrated during questioning after the children had tested out their designs and were successful. I asked questions such as:

> *Did you make the boat/bridge like your original design?*
> *What did you change? How come?*
> *Why didn't the first design work?*
> *Why did it work after you made the changes?*

These open-ended questions allowed the children to reflect on the previous stages of the design process and answer accordingly.

Overarching Social and Emotional Capabilities (SE)

With the overarching social and emotional capabilities from cycle one to cycle two, there was an observed increase across all indicators. However, from cycle two to cycle three, there were increases in all indicators apart from the *Uniqueness indicator* (SE4) which remained the same from cycle two to cycle three with two indicators each.

From cycle one to cycle two, the *Resilience indicator* (SE1), increased from three to ten. From cycle two to cycle three it decreased from ten indicators to two. In cycle one's learning story (Appendix C LS1.4) where Ava join's Sarah building a Mobilo train, Ava did not stay with the task as it kept breaking when she pushed it. Instead of helping solve the problem she said, "I'm not doing it, I'm going to play in the home corner." Ava did not demonstrate resilience due to the fact that it was not her initial idea to make the train. She wasn't as invested in making it work, gave up and decided to play elsewhere. However, in cycle two where Ava created a floating boat for Sally, her first design was unsuccessful but she was eager to try again and helped to create another boat, this time successful in floating.

The *Collaboration indicator* (SE3) had three indicators in cycle one, eight indicators in cycle two and five indicators in cycle three. This showed an increase from cycle one to cycle two, a decrease from cycle two to cycle three, but an overall increase between cycles one and three. In cycle one, the children were observed engaging in everyday play or were asked to create something of their choice using the constant resources in the environment. The observations were taken during children's everyday play, sometimes randomly with children working in pairs or groups, or when asked individually if there were no other participants available in that time. Cycle two was a set activity that required planning, and therefore I was able to pair children together based on their attendance days and their friendship groups to keep them comfortable in their play. The children engaged in more collaboration during the implementation of the design process as there was a problem and clear goal for the children to achieve and I asked more open-ended questions in which all participating children could voice their thoughts.

Total Number of Indicators

The combined number of indicators of creativity for cycle one was lower, at 52, than cycle two with 132 indicators and cycle three with 60 indicators. There were fewer observations in cycle one than cycle two with six observations in cycle one but eight observations in cycle two. However, each observation in cycle one comprised one activity, but in cycle two with the implementation of the design process, the children took longer to complete the activity. For the children to successfully create a product, Adam and James took three sessions to create a floating boat, Ava and Sarah took two sessions and Olivia and William took one session each. Therefore, there were four engineering design processes implemented as opposed to the six observations in cycle one.

There were only two engineering design processes implemented in cycle three. The bridge activity for cycle three was easier for the children to complete than the boat in cycle two. Looking at the number of indicators of creativity, some were the same or less than in cycle one or two as there were only two observations. However, in the ideation stage, the *Asking Questions* (I1) and *Challenges indicators* (I2), increased by cycle two. It is possible that after already going through the engineering design process in cycle two, the children were comfortable with the process and knew what to expect. Even though the number of indicators in cycle three was less than cycle two, there were still six more indicators than cycle one. Furthermore, Ava left the centre after cycle two so the number of children participating in cycle three dropped to five.

Time

Another observation from the data was that the time frame for observations increased from cycle one to cycle two but plateaued from cycle two to cycle three. The increase from cycle one to cycle two demonstrated that by incorporating a design process, engagement levels improved but there was a decrease or equal amount of time of sessions from cycle two to cycle three. The reasons for this could include the degree of difficulty for activities in cycle two to cycle three, with cycle three being an easier activity. It could also be, as mentioned above, that the children were becoming comfortable with the design process.

Trial and Error

After implementing the design process, the children increasingly engaged in trial-and-error behaviour during the creating stage. Ava and Sarah trialled their boat twice before being successful, whilst Adam and James trialled their boats four times before accomplishing their goal. In cycle one, no children demonstrated trial and error other than Adam (Appendix C, LS1.3) when he added another column to his tower to add support after the original fell, and Sarah in (Appendix C, LS1.4) where she tried another type of Mobilo plug for her train.

In summary, key findings to emerge from the cross case analysis indicated:

- An increase in the time spent during sessions in each cycle demonstrating higher engagement levels for the children
- An increase in reflection throughout all stages resulting in successful creations due to changes to original designs
- An increase in children challenging other ideas or assumptions, proposing and giving reasons for possible solutions and imagining multiple uses for an object during the ideation stage
- The creative use of materials in ways other than what they were intended to be used for, and
- An increase in social and emotional capabilities such as resilience and perseverance, and collaboration.

4.11 Educator's Pedagogy and Practice

My pedagogy and practice developed throughout the study through critical reflection after each session and whilst writing the learning stories. The *I Wonder* section of the learning stories included future suggestions that the children could be interested in pursuing as well as critical reflection of my pedagogy and practice. I Wondered what I could have done differently and what I could change for the next session. In cycle one (Appendix C, LS1.3), I reflected whether the inclusion of the Inquiry Questioning Model would give more guidance to the children in their play and result in higher order thinking, as follows:

> *I Wonder if using the Inquiry Questioning Model will allow for more cohesiveness among the children's ideas and during the creating process. Will the children have more of a plan about what they're going to make rather than making it up as they go along and not just connecting/placing pieces without everyone understanding why once the Inquiry Questioning Model is introduced? I Wonder if having some questions planned using the Inquiry Questioning Model will help me to encourage higher order thinking resulting in an increase of creativity indicators?*

In reflection, LS1.2, I speculated on James' creation of a bus using paper, Textas and fabric:

> *I Wonder if I could have used different questions to provoke James into creating a 3-dimensional version of the double decker bus. Next time I could*

give him a variety of resources to create with and ask him to make the double decker bus.

Instead of creating a bus, the engineering design process for cycle two involved creating a three-dimensional boat using a variety of materials. The nature of the Inquiry Questioning Model in cycles two and three did allow for more open-ended questioning, provocation, and higher order thinking for the children. In cycle two, reflection LS2.3, I used questions to see if James and Adam understood that some materials are waterproof and others are not, as follows:

Me: What happens if you put paper in the water?
Adam: It will sink
James: It won't sink, it will get wet
Adam: And then it will sink down, down deep
Me: So what do you think will happen if you put the cardboard box in the water?
James: It will rip
Me: Do you think this material is better? The plastic?
James: Yeah.

The following demonstrates the questioning used in LS2.2,

Me: What do we need to do to make Sally float?
Sarah: We need a bigger one
Ava: Make it heavy
Me: What would happen if you made it heavy?
Ava and Sarah: Float
Pause by myself and children
Sarah: If it's too heavy it will sink

My reflections in cycle one allowed for me to better prepare the questions I used in cycles two and three to encourage the children to vocalise and demonstrate their thinking rather than answering for them. In reflection LS2.3 I Wondered whether it would be better to show the materials available before the children drew their designs as this would impact their drawings, as follows:

I Wonder if I show the children the materials before their drawing, if it would make a difference and they will be able to stick to their original designs?

From this, I subsequently showed the children the variety of materials and resources available before asking them to draw their designs. This worked better as the designs looked more accurate to their final product. In summary, these examples demonstrate the importance of critical reflection on personal practice and pedagogy to developing higher order thinking and assist children to voice their ideas and thoughts.

4.12 Summary

This chapter has set out to present the findings of the research for each individual child participating in the study, as well as a cross case analysis of all six children. The chapter has briefly discussed the common themes which emerged from the indicators of creativity checklist, and lastly, it has presented examples of my reflections on my pedagogy and practice throughout each cycle of action. The next chapter now discusses the findings from this chapter in relation to the research questions and makes recommendations for practice.

Chapter 5. Discussion

5.1 Introduction

The previous chapter presented an overview of the findings from the three action cycles, including the findings for each child drawn from the indicators of creativity checklists, learning stories and my critical reflections. It then presented a cross case analysis of all six participating children and the emergent findings across all three cycles across all children as well as implications for educator pedagogy and practice. This chapter now answers the research questions through discussing the findings in relation to relevant literature.

The chapter commences by briefly answering the research questions and discussing them in relation to the findings presented in chapter 4. It then discusses the findings in relation to the literature presented in chapter two and concludes with recommendations for future practice drawn from the study.

5.2. Answering the Research Questions

This study set out to investigate the implementation of an engineering design process with children aged three and four and was guided by the following research question.

> *How do young children respond to the intentional inclusion of an engineering design process in early childhood integrated STEM activities?*

The children responded positively to the intentional inclusion of an engineering design process as evidenced in chapter 4. The children spent more time designing, creating, and reflecting in cycles two and three after the implementation of the design process. They displayed greater engagement and increased self-determination and resilience, and there was evidence of greater collaboration between peers. Further, through my own reflections when writing the learning stories, I was able to refine my practice. This includes the types of questions I asked the children and the order in which I presented the design process. At first, I asked the children to draw their designs before showing them the materials and resources available for creating their boats. After some reflection, I found it was better to show the children the materials before asking them to draw their designs so they had an idea of what they could use, improving their engagement and my pedagogy.

In addition to the main research question, the study employed three sub-questions. Sub-question 1. *How can an engineering design process be adapted and implemented in young children's play (three and four years old)?*

This project showed an engineering design process can be successfully implemented with young children with the guidance of an educator. By using the Inquiry Questioning Model, I was able to introduce the design process in an age-appropriate manner, based upon the children's interests and in a playful way. This encouraged the children to engage with and complete the two activities as it was relevant and meaningful to them.

Sub-question 2. *How can young children's development of creativity be monitored*?
In relation to sub-question 2, using the creativity indicators checklist when engaging in the sessions with the children provided me with the opportunity to focus on the indicators of creativity closely. Having a checklist allowed me to look for the creative behaviours when writing the learning stories after each session. It allowed for an emphasis on the children's creative development as I was more aware of the dimensions of children's creativity and it guided me on what to look for. The checklist was a valuable tool in identifying creative elements when used after each session whilst writing up the learning stories.

Sub-question 3: *How does the design process effect young children's demonstration of creativity?*
The design process gave their creativity a purpose as the children were given problems they needed to solve. The fact they were able to solve them indicated that children of this age can demonstrate high levels of creative thinking especially in relation to using objects in ways other than their intended use, reflection and evaluation, resilience, and collaboration. The cross case analysis in chapter 4 showed that the total number of creativity indicators significantly increasing from cycle one with 52 indicators, to cycle two with 132 indicators. There was also an increase from cycle one to three of eight indicators even though there were four less observations and one less child involved (Table 4.13). This increase in indicators implies that the inclusion of the design process positively affected young children's creative capacity by focusing on specific tasks associated with creative thinking. The rest of the chapter now discusses the project in more detail according to the findings and literature.

5.3 Introducing an Engineering Design Process to Young Children in a Play-based Setting

This project set out to introduce an engineering design process in response to reported issues surrounding STEM and creativity. Kelley and Knowles (2016) reported a decline in adolescents and young adults undertaking STEM subjects, while Pantoya et al. (2015) stated that the decline of interest in STEM is evident even by fourth grade. Sternberg (2007) reported a decline in creativity among adolescents while Yates and Twig (2017) have identified the trend of students creating identical products and teacher directed lessons as contributing factors to the decline.

In this study, I introduced the engineering design process to the children aged three to five years in the form of an Inquiry Questioning Model (Murcia et al., 2020a). I chose this model as it allowed me to prepare the session with open-ended questions in mind to facilitate the STEM learning, creativity and higher order thinking within the process. Early childhood settings plan and document learning by following the planning cycle in which the educators gather information about the children, question and analyse this information, plan, implement, and reflect and evaluate (ACECQA, 2015). The setting uses a variety of templates and means for conducting the planning cycle. I used the Inquiry Questioning Model proforma as part of my regular planning. The Inquiry Questioning Model included resources for the activity but goes into greater detail to include science and mathematics concepts and language, and the inquiry questioning to be used. This is important as it emphasises the STEM learning that can occur through the use of the model. The addition of this preparation of questions is not often observed in the regular early childhood practice and open-ended questioning is usually undertaken in the moment whilst the activity is underway.

The preparation of the questions allowed me to ensure all activity stages of the design process were accounted for and higher-order thinking questions were asked. Previously, in the moment of teaching these types of questions could be missed. Importantly, the inquiry questions helped led to an increase in reflection and evaluation among all the children. This is evident in the cross-analysis findings (see Table 4.13) where the percentage frequency of indicators increased from 3.8% in cycle to 5.4% in cycle two and 8.6% in cycle three for *Reflecting critically* during the creative process. *Reflecting critically* on ideas and processes for solving problem or constructing the product increased from 0% in cycle one to 4.6% in cycle two and 6.9% in cycle three. Lastly, *Evaluating the product* for originality, effectiveness and being fit for purpose increased from 0% in cycle one to 8.5% in cycle two and 8.6% in cycle three. This indicates that the more the Inquiry Questioning Model was used, the more the children were reflecting on their ideas, problems, and products, with reflection being a key indicator of creativity according to the *A to E of Creativity Framework* (Murcia et al., 2020b). The use of this model in my project supported intentional teaching as the children demonstrated increased problem solving, higher order thinking and engaged in shared thinking through planned open-ended questions. The EYLF (2009) states that:

> *Educators who engage in intentional teaching recognise that learning occurs in social contexts and that interactions and conversations are vitally important for learning. They actively promote children's learning through worthwhile and challenging experiences and interactions that foster high level thinking skills. They use strategies such as modelling and demonstrating, open questioning, speculating, explaining, engaging in shared thinking and problem solving to extend children's thinking and learning* (p. 15).

The findings of this study indicated an increase of indicators of creativity after the Inquiry Questioning Model was introduced. Cycle one's total number of indicators was 52, but after the introduction of the model, this increased to 132 indicators in cycle two and 60 indicators in cycle three. This aligns with other research which also reports that inquiry-based learning increases creativity, problem solving and collaboration (Chu et al., 2016). Chu et al. (2016) stated that IBL usually begins with educators asking the children questions to be answered through further questioning rather than answers. By doing this, the educator supports children's individual thinking and promotes problem solving as well as knowledge building. In this study, I introduced a problem for the children to solve in cycle two and three, namely, how to get Sally across the river and how to get the Three Billy Goats Gruff across the bridge. I then used open ended questioning as a strategy to facilitate children's learning, by assisting the children to solve the problem themselves.

The Inquiry Questioning Model used for this study also lends itself to play-based learning. Barblett et al. (2016) discuss play-based learning (PBL) whereby educators plan activities for children to learn skills and concepts based on their interests in a way that is pleasurable, engaging, and exciting. In this study, I observed the children in the first cycle to see what their interests were. There was a general theme around transport which led to the cycle two activity of creating a boat. As the EYLF (2009) defines play-based learning as, "a context for learning through which children organise and make sense of their social worlds, as they engage actively with people, objects and representations," (p. 6), the Inquiry Questioning Model encourages young children to explore the world around them through the higher order questions posed by the educator therefore resulting in deeper thinking (Murcia et al. 2020a). As well higher order questionings, the Inquiry Questioning Model incorporates social interaction amongst peers with scaffolding and information given from peers to foster learning (Murcia et al. 2020a). This was demonstrated in this project and can be seen in the learning stories, especially around the reflection stages during the creation stage. The children collaborated and engaged with mostly recycled materials to create a final product with opportunities for learning along the way.

As the participants were of a young age, the Inquiry Questioning Model allowed for an adaptation of the engineering design process used by adult engineers, to become age appropriate for the young children in this study. The children were introduced to the design problem to solve, how to get Sally the doll across the river. I showed the children photos of a river, and then photos of a variety of different types of boats and the provocation set up with recycled materials and resources for the children to use. This prompted the children to give ideas about what type of boat they wanted to make and what it would look like. It allowed for discussion about boats, what makes them move, design aspects and the different materials they could use, whether they would be suitable for water and whether they would float or sink. The process encouraged children to experiment and problem-solve for themselves, leading to independent learning. This is a very important finding in terms of the role of the educator in guiding children through the process.

In summary, by using the Inquiry Questioning Model (Murcia et al., 2020a), I was able to intentionally implement the engineering design process to young children based on their interests, in a playful manner that encouraged and developed their creative thinking and STEM skills.

5.4 Enhancing an Educator's Practice Through Action Research and Critical Reflection

Park et al. (2016) stated that educators' confidence towards teaching and implementing STEM engineering activities with young children is low. To combat this, the inclusion of an Inquiry Questioning Model as used in this study has the potential to provide educators with a pedagogical template of how to conduct engineering design projects with young children. This template offers educators insights in how to plan to conduct the sessions, the resources needed, the questions to ask the children to scaffold their STEM knowledge and how to go about conducting the engineering design process in real time, which in turn has the potential to build educators confidence to introduce these concepts to young children. The addition of the Inquiry Questioning Model enhanced my personal teaching practice as I was able to focus on specific STEM principles and ways to stimulate creativity. I gained a better understanding of the construct and characteristics of creativity after devising the checklist. Therefore, I was able to observe children's creative development in more detail than in my previous practice.

Another tool used to enhance practice was the learning story template which is an already widely accepted practice in the early childhood setting. However, I modified the setting's learning story template headings to include *I See, I Think, I Wonder* from the Harvard Visible Thinking Routine (Lowe et al., 2013). The 'Story' section became the *I See* section, the 'analysis of learning' became *I Think* and the 'Implications for future practice' became the *I Wonder* section. By making these changes, I was able to critically reflect more deeply than in previous practice as I was able to ask myself what I thought happened in the session, where I could go next in my practice and how the children might respond. As a result, the learning stories became more detailed than they would have previously been, and I was better able to plan for future interactions with the children.

Ultimately, through action research, I was able to reflect upon my own practice to enhance it for the future, with the children benefitting from the experience. Creswell (2008) states that action research allows for reflective practice because of its cyclical nature. By engaging in action research, not only did my practice improve throughout the project but also my overall pedagogy and practice for the future through an enhanced understanding of creativity and its components, and my enhanced ability to self-reflect. The difficulties I encountered were more related to the early childhood setting where children did not attend daily. Being the practitioner as well as researcher, having another person take photographs whilst I engaged with the children would have allowed for better flow of the sessions. However, it is generally common practice in early childhood centres to interact with the children as well as document learning through photographs and informal observations. I found the action research method a valuable way to approach research to assist educators in solving issues in their own settings and critical reflection on their pedagogy and practice, as well as being valuable for the education of the children involved and children the educators may teach in the future. It has the potential to inspire other educators either within the same education setting or outside to explore issues they may face in their classrooms or subjects they would like to further explore (Creswell, 2008).

Aligning with the constructivist approach, I guided the children through open-ended questioning, rather than supplying the answers and instructing the children on what to do. Pritchard and Woollard (2010) discussed social constructivism in the early childhood setting whereby young children are seen as capable learners through social interaction, language and self-reflection. This was evident in this project especially after the introduction of the Inquiry Questioning Model where children's collaborative abilities notably increased, and my practice around open-ended questioning improved. I paired the children in cycle two and grouped them for cycle three to allow for this social interaction which supports Krause et al. (2010) assertion that social constructivists believe social interaction is imperative to learning.

The children were paired with a friend, dependent on the day in which they attended to make them feel safe, secure, and supported to voice their ideas and opinions. Ava and Sarah were paired in cycle two after already working together naturally in cycle one, and Adam and James worked together in cycle two. Olivia worked by herself as she would only be at the centre on the same day as other participants every second week and William was a late addition to the study as a previous participant withdrew having left the centre. In cycle three, Sarah and William worked together as Ava withdrew from the study having left the centre and Olivia joined Adam and James to complete cycle three. From cycle one to cycles two and three, there was an observed increase in *Collaboration indicators* from 3 (5.8%) in cycle one, to 8 (8.5%) indicators in cycle two and 5 (8.6%) indicators in cycle three. I believe the inclusion of the Inquiry Questioning Model encouraged greater collaboration as the children worked together to solve a problem whilst I scaffolded learning through the questioning process so that all children had the opportunity to contribute their thoughts and ideas.

I became more intentional during the study after devising the indicators of creativity checklist. I actively looked for these indications of creativity after gaining more of an understanding through my initial literature review. Using learning stories, I was able to reflect on my pedagogy and practice and refine my questioning skills to the benefit of the children in this study. Through this reflection, I became more intentional with the language I used to ensure I was clear, and the children could understand what I was asking them. This benefited their indicators of creativity including engagement and participation, the success of their creations, as well as verbalising their ideas and reflections.

5.5 Using an Indicators of Creativity Checklist to Assess Children's Creativity

The notion of creativity and what constitutes a creative individual has been examined over the years through the work of Guilford (1950) who discussed creativity as a personality trait, and Torrance (1977) who created a test to measure children's creativity named the Torrence Tests of Creative Thinking. In more recent years, Sternberg (2007) discussed creativity as a habit having devised 12 keys for developing the creative habit in children. I used attributes from each of these key theorists, including problem solving, integrated learning, imagination, questioning and more to devise the Indicators of Creativity Checklist. The *A to E of Creativity* framework was also used for the creation of the checklist which was expanded to include the Overarching Social and Emotional Capabilities of the children (Murcia et al., 2020b). For this study, the checklist was employed as a tool to observe characteristics of creativity in the children whilst they were engaging in the unplanned and planned activities. As I conducted the sessions by myself, the checklist was used after the sessions whilst I relistened to audio and wrote up the learning stories, analysing the data as I did so. It would have been too complicated and disruptive to the flow of the session to use the creativity checklist during the sessions as I was engaging with the participating children, implementing the design process, and taking photographs. However, the creativity checklist proved to be a valuable tool as it allowed me to focus on specific defining aspects of the children's creative development. Having the checklist divided into the stages of the design process made it easy to use as it was in a sequential order. As I wrote the learning stories, I could easily mark off any indicators the children demonstrated. Most indicators increased from cycle one to cycle two, however the reflection indicators, using objects in a way other than their intended use, and social and emotional capabilities of collaboration, occurred most frequently, increasing in each cycle.

There is as yet, limited research around creativity in early childhood, specifically around STEM education. Yates and Twig (2017) claim that there is more of a focus on creativity in subjects such as art, music, dance and design and technology than in cross-curricular approaches. While one study conducted by Pantoya et al. (2015) reported that young children's creativity was enhanced after introducing engineering-centred literacy, in general, there is little creativity research in the early childhood field especially in relation to STEM education which then makes this study, and particularly the use of the creativity checklist, all the more relevant.

Knauf (2018) discussed the value of learning stories as a method for assessing children's learning where educators document, then analyse and reflect on children's learning. During this study, the learning stories played a role in monitoring creativity as they included transcripts of what the children said, and my responses, questions and reflections.

ACECQA (2015) discuss the importance of the planning cycle as a means for gathering information, questioning, and analysing, implementing, and reflecting and evaluating. The Indicators of Creativity Checklist, used as a tool after the implementation of each activity, allowed me to evaluate each child's learning, both individually and collectively. It also gave me a more focused lens on creativity than just writing the learning stories which are already an established part of the centre's practice. After having completed the checklist, each child's indicators were tallied and percentages identified, and finally a cross case comparison made of the total number and percentage of indicators in each cycle. From this, I was able to identify an increase in the number of indicators as previously described. Ava demonstrated an increase in persistence, engagement, resilience, reflection and a change in material use, whilst Sarah displayed an increase in reflection and time from cycle one to cycles two and three. Adam showed an increase in time, resilience, reflection, questioning and change in material use. Olivia demonstrated an increase in time, perseverance, autonomy and change in material use. James showed increased time, reflection, and resilience. Lastly William demonstrated an increase in time, reflection, challenging assumptions and change in material use from cycle one to cycles two and three.

While each child displayed increases in different creativity indicators, overall, the main indicators that increased through implementation of the engineering design process as evidenced by the creativity checklist were challenging ideas or assumptions, proposing and giving reasons for possible solutions, and imagining multiple uses for an object indicators during the ideation stage. During the creation stage, there was an increase in the creative use of objects in ways other than their intended use and throughout all the stages, indicators of reflection and evaluation increased. Social and emotional capabilities such as resilience and perseverance and collaboration increased after the implementation of the engineering design process.

By using the indicators of creativity checklist, I was able to identify and document improvements in children's creativity. I found the checklist easy to use and allowed for a targeted emphasis on all the elements associated with children's creativity development. This relates directly to the second research sub-question: *How can young children's development of creativity be monitored?*

5.6 The Engineering Design Process as a Method for Increasing Creativity

In the findings chapter, table 4.8 presented a cross case comparison of all participants frequency of indicators. These findings indicated an increase in creativity from cycle one, with 52 indicators demonstrated, to cycles two and three with 129 indicators and 60 indicators following implementation of engineering design process. As discussed in the findings chapter, there a range of possible reasons for a drop in the number of indicators from cycle two to cycle three, including the greater complexity of the activity in cycle two compared to cycle three, and therefore an increase in the number of sessions taken to complete the activity with more opportunities to demonstrate indicators of creativity. The increase in creativity recorded after the introduction of the engineering design process supported the initial hypothesis and aligns with the study findings reported by Pantoya et al. (2015) that children's creativity did increase following an introduction to engineering literature as well as Sternberg's (2007) assertion that integrated learning and problem solving develops creative habits in young children.

The increase in creativity evidenced in this study, along with the integrated nature of STEM, engineering design process and the problem solving that the participants engaged in cycle two with the aim of creating a successful, floating boat, were documented in the learning stories. The findings in the cross case comparison show that the participants 'generated a solution to solve a problem' equally with seven indicators for cycles one and two, and three indicators in cycle three. The participants also demonstrated 'tries out new arrangements or approaches' with six indicators in cycle one, increasing to ten indicators in cycle two, but decreasing to two indicators in cycle three. Another problem solving indicator, 'proposes and gives reasons for a possible solution', was not demonstrated in cycle one, but appeared in cycle two with six indicators observed and two indicators in cycle three. All these problem solving indicators either remained the same from cycle one to two or increased but decreased from cycle two to three and some decreased from cycle one to three. This decrease can be explained by the degree of difficulty of the activity in cycle three being easier to achieve than the activity in cycle two as well as the number of allocated sessions. It only took two sessions, one for each group of children, to solve the problem of the getting the Three Billy Goats Gruff across the river compared to the six observations in cycle one and eight observations in cycle two.

In addition, there was an increase in the amount of time the children spent engaged in each session after the introduction to the Inquiry Questioning Model. The findings revealed that all participants spent more time completing the boat making activity as opposed to the cycle one activities prior to the introduction of the Inquiry Questioning Model. Some of the children spent a greater amount of time in the individual sessions than those in cycle one. Sarah, Adam, Olivia and William all demonstrated an increase in time spent in cycle one compared to cycle three, whilst James was the only participant who spent a longer time on his cycle one activity opposed to the cycle three bridge building activity. His cycle one session ran for 30 minutes, and his cycle three session ran for 25 minutes, a five-minute decrease.

The overall increases in time demonstrate an increase of engagement levels similar to the reported findings of Aubrey and Dahl (2013) in relation to their work in Reggio Emilia settings in engaging children's minds and imaginations. Sternberg (2007) asserts that creative individuals improvise and demonstrate flexibility when they solve problems. The findings in this study revealed an increase in the ideation stage of cycle two where there were three instances of children demonstrating the proposes and gives reasons for a possible solution indicator, as opposed to none in cycle one.

In summary, the emerging themes and the increase in indicators following implementation of the design process reported in this study validated its inclusion in that the design process positively affected and increased participating children's demonstration of creativity, answering the third research sub-question: *How does the design process effect young children's demonstration of creativity?*

5.7 Recommendations for Practice

Having discussed the findings of this study in relation to the research questions and supporting literature, the study now makes a series of four recommendations for practice.

Recommendation 1: Early childhood educators should be offered STEM focused professional learning and development

The first recommendation is that early childhood educators be informed of the potential of the engineering design process. Given reported declines in STEM and creativity among young children, educators need to be informed of the value of the engineering design process to not only increase young children's STEM learning but also their creativity. Accordingly, it is recommended that targeted professional development be offered to all early childhood educators into the engineering design process as part of their ongoing professional development requirements. This will allow early childhood educators to feel confident in delivering STEM engineering in their settings and provide them with effective procedures for pedagogical development.

Recommendation 2: Pre-service teachers are educated in the use of an engineering design process with children and the dimensions of creativity.

The second recommendation is that pre-service teachers are educated in STEM engineering and creativity development. It is recommended that before educators enter the workforce, they are all fully equipped with the knowledge and understanding of STEM engineering and creativity development by embedding these areas into their Initial Teacher Education (ITE) courses. These are vital for young children's learning and development as a foundation for their future learning and careers. If teachers have this knowledge prior to commencing in the profession, they will be more able to readily implement and foster STEM engineering learning and creativity development in their individual settings. In addition, pre-service educators should be equipped with effective strategies to develop their pedagogy and practice once in the profession.

Recommendation 3: Policy makers and stakeholders are informed of the significance of STEM engineering and creativity in early childhood education.

The third recommendation is that policy makers and stakeholders are informed of the significance of STEM engineering and creativity development in early childhood to inform their work in this space. The reported issues of declines in STEM engagement and creativity needs to be highlighted to policy makers and stakeholders for change to occur. If they understand the importance of creating strong foundations in the early years around these areas, the generation of adults and future leaders will be equipped with twenty-first century skills to deal with future issues in the world. This needs a sector wide response to ensure all children are given the opportunity to develop STEM engineering skills and dispositions, and foster their creative development.

Recommendation 4: Professional learning and development programs in STEM education for children be developed by sector-wide training organisations.

The fourth recommendation is that professional learning and development providers such as Early Childhood Australia and other private consultants provide professional development programs for early childhood educators focused on STEM. Within this overarching focus, professional development can include how to deliver the STEM engineering design process in early childhood settings, the impact of the engineering design process on young children's creativity and how to monitor young children's creative capacity. Further, it is also vital that educators are made aware of how they can develop their pedagogy and practice through processes such as critical reflection.

5.8 Summary

In summary, this study has demonstrated that through the intentional introduction of the Inquiry Questioning Model, the engineering design process can be adapted and implemented for young children in a playful manner, based on their interests, whilst they develop their creativity and STEM skills and dispositions. By using the indicators of creativity, I was able to identify and monitor the children's creativity development and saw an increase in their creativity after the introduction of the Inquiry Questioning Model. The children responded positively to the intentional inclusion of an engineering design process, demonstrating an increase in social and emotional capabilities such as resilience, determination and collaboration as well as other creativity indicators including reflection and evaluation, and the selection and use of materials.

This chapter set out to answer the research questions and discuss them in relation to the findings presented in chapter 4. It has then discussed the findings in relation to the literature presented in chapter two and concluded with recommendations for future practice drawn from the study. Most importantly, this study has demonstrated age-appropriate ways to implement STEM engineering through an Inquiry Questioning Model to enhance young children's creative capacity, and has been beneficial to the ongoing development of my pedagogy and practice as an early childhood educator. It will add to the limited literature surrounding this topic and support early childhood educators in their pedagogy and practice, and has the potential to help improve STEM engineering and creativity outcomes for the future.

The following chapter now concludes the thesis by reiterating the study aim, the significance of the study, the limitations of the study and makes recommendations for future research.

Chapter 6. Conclusion

6.1 Introduction

The previous chapter set out to answer the research questions, in relation to the findings presented in chapter 4. It then discussed the findings with reference to the literature presented in chapter 2 and concluded with recommendations for future practice drawn from the study. This chapter now concludes the thesis.

The chapter reiterates the aim and significance of the study in relation to the problem statement as outlined in chapter 1. It then presents the limitations of the study, recommendations for future research, and finishes concluding remarks as to the value of the engineering design process as a pedagogical process for encouraging creative thinking among young children in early childhood settings.

6.2 The Aim of this Study

This study identified the problem of declining STEM interest and creativity. The study set out to encourage STEM engineering engagement in the early childhood years, particularly in relation to young children's creative capacity. It asked the following overarching research question:

> *How do young children respond to the intentional inclusion of an engineering design process in early childhood integrated STEM activities?*

To answer this question, an action research approach was undertaken and, as a practitioner researcher, I implemented a STEM engineering design process with a creativity lens in an early childhood setting with children aged three and four years old.

Using social constructivism as its theoretical base, the study found that young children respond positively to the intentional inclusion of the engineering design process with an overall increase of indicators of creativity observed after implementing the Inquiry Questioning Model. Through this implementation, greater engagement was observed as the time the children spent working on their designs in the experiences increased, as well as their overarching social and emotional capabilities including collaboration, resilience, and self-determination. The children demonstrated more trial and error, problem solving, reflection, and evaluation, higher order thinking skills, and the creative use of a variety of objects. These indicators of creativity were highlighted by using the checklist, derived from the Murcia et al.

(2020b) *A to E of Creativity*, allowing for a specific lens of creativity. Not only did the children benefit from the study, but also my pedagogy and practice improved by using critical reflection throughout the study, derived from the Harvard Visible Thinking Routine of *I See, I Think, I Wonder*.

6.3 The Significance of the Study

The findings of this study are significant because of the reported declining interest in STEM and creativity in young children and adolescents. To combat this issue, more engagement in STEM is needed in the early years. However, many educators are unsure of how to implement STEM, specifically approaches such as the engineering design process, in their early childhood settings. There is limited research involving engineering design processes and young children. Using an Inquiry Questioning Model, this study used age-appropriate experiences to implement STEM engineering, enhancing young children's creative capacity which adds to the limited research regarding this topic.

The findings also show that through critical reflection via the learning stories, an educator's pedagogy and practice can be improved. By reflecting on the questions I asked the children and the delivery of the Inquiry Questioning Model, I was able to enhance the children's experiences and their learning. The critical reflection occurred after each session whilst writing the learning stories, which incorporated the Visible Thinking Routine *I See, I Think, I Wonder*. Also, by using the indicators of creativity checklist, I was able to identify and focus on the children's creativity. This demonstrates that by using assessment tools such as learning stories and the indicators of creativity checklist, as well as critical reflection in general, an educator's practice can be improved.

To improve interest in STEM engineering and enhance creativity, it is recommended that educators implement STEM engineering in their early childhood settings. Early childhood educators build the foundations for positive future learning, and therefore it is vital that young children are exposed to STEM in the early years. Based upon its findings, this study has made a series of recommendations for practice, which can be summarised as:

- Early childhood educators be informed of the potential of the engineering design process for encouraging children's interest in STEM and the creative thinking process
- Pre-service teachers be educated in the use of the STEM engineering process and its capacity to develop children's creativity

- Policy makers and stakeholders be informed of the significance of the engineering design process and its capacity for encouraging interest in STEM as well as in terms of creativity development in early childhood.
- Professional development providers include the engineering design process as a requirement for early childhood educators to help encourage children's interest in STEM and build their creative capacity.

6.4 The Limitations of this Study

It is acknowledged that there can be issues associated with the generalisability of the findings as only six children participated in this study. While the number of participants were limited, the study is still of value to the STEM engineering and creativity literature as there is a lack of research in this field. The findings of this study will assist in STEM engineering skills and dispositions and young children's creativity. It will also encourage other early childhood educators to develop their pedagogy and practice surrounding these topics.

Due to the nature of the qualitative data and in line with my epistemological position, the findings represent my interpretation of children's verbal and non-verbal language, and indicators of creativity that were observed. It is understood that another reader may interpret the learning stories differently. However, I have endeavoured to maintain trustworthiness throughout the study. I have guaranteed credibility through data triangulation, transferability by using rich descriptions in my findings, dependability by acknowledging my assumptions and biases as well as writing in the first person, and confirmability by being clear and transparent throughout the study, ensuring the accuracy of data. While I am confident in the veracity of my findings through the use of the creativity checklist and learning stories, it would be beneficial for future studies to employ alternative methods such as video recording and interviews for a more diverse view of young children's creativity and STEM learning.

Stahl and King (2017) state that confirmability is "getting as close to objective reality as qualitative research can get," (p. 28). By using many different methods within my study, I have attempted to ensure the accuracy of data and I have been clear and transparent throughout all stages of the research.

The setting of the study, being an early childhood centre working with young children, generated some difficulties. In a school setting all the children attend each day, however in the early childhood setting, not all children attend on the same day. This meant that if any activity needed to be revisited, it was undertaken a week later or more depending on any absentees. Also, being a team leader and taking on a new role as education support meant I was taken out of the room more and other duties took priority. This in turn created time pressure to complete the data collection. As I was a practitioner researcher, I only conducted the research in my own setting. While I selected children of varying cultures and genders within my setting, I was unable to include children from other socio-economic backgrounds, more cultures and other early childhood centres or schools. There would be value in extending the timeframe to include more cycles of action, other age groups and a variety of settings including schools and community kindergartens where a wider range of children's cultures and socio-economic backgrounds could be explored.

6.5 Recommendations for Future Research

This study was undertaken to explore STEM engineering and creativity as they are both reportedly in decline amongst adolescents and have been noticeably decreasing in younger age groups. There has been little research undertaken in this area and there is a need for further investigation to build on the findings of this study to allow for greater generalisability in other settings, with children of different ages, cultures, and socio-economic backgrounds.

The Inquiry Questioning Model was used in this study as the engineering design process. It is recommended that this model be employed in future research into young children's creativity and development of STEM skills. This study also included an indicators of creativity checklist which I devised based on creativity literature for the purpose of this study. It is recommended that further investigation be conducted into the indicators of creativity, and the veracity of the checklist itself as this is the only study in which this tool has been used.

The study found the use of learning stories helpful as a means for aiding critical reflection on educator's practice. It was adapted from the Harvard Visible Thinking Routine, *I See, I Think, I Wonder*. It is recommended that in future, the use of learning stories, the effects of learning stories on educator's pedagogy and practice, and the adaptation of the learning stories to include the Visible Thinking Routine be further explored.

Finally, as there were only two cycles of action implementing the Inquiry Questioning Model, there is a need for research to be conducted to demonstrate more ways educators can implement an engineering design process using this model. This will also further assess the value of the Inquiry Questioning Model in the STEM context, and some more formalised research involving quantitative data would also be useful.

6.6 Summary

STEM is an increasingly important subject area and along with creativity, is vital for future generations in supporting their careers and solving current and future world problems. This project was stimulated by my interest in STEM, creativity, and young children's education. As a passionate early childhood educator, I was wanting to enhance my pedagogy and practice, so I implemented an intervention to enhance young children's STEM skills and dispositions as well as focus on their creativity development. Through the research process, I have grown as an educator and found it successful in increasing young children's creativity. I also found it beneficial to my own pedagogy and practice, learning much from the process as an educator as well as personally. I hope my research journey inspires other early childhood professionals to develop their own pedagogy and practice, and provide young children with rich learning opportunities which foster their creativity and STEM skills and dispositions.

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Appendices

A. Indicators of Creativity Checklist

Key
Cycle 1 Cycle 2 Cycle 3

Indicators of Creativity Checklist

Child's Name:	Ideation (I)							Creation (C)			
	Asks questions	Challenges other ideas or assumptions	Proposes multiple ideas for design	Reflects critically on ideas	Makes connections between things that are not usually connected	Proposes and gives reasons for a possible solution	Imagines multiple uses for an object	Establishes a purpose for their actions	Draws together two ideas or objects to propose something new	Uses an object in a way other than its intended use	Modifies initial design
1. Ava				22/10/19		22/10/19		28/5/19 4/6/19 22/10/19 19/11/19		22/10/19 19/11/19	19/11/19
2. Sarah	10/12/19	21/5/19	28/05/19 22/10/19	19/11/19 10/12/19	22/10/19	19/11/19		21/5/12 4/6/19 28/5/19 22/10/19 19/11/19 10/12/19	21/5/19 19/11/19	21/5/19 22/10/19 19/11/19 10/12/19	4/6/19 22/10/19 19/11/19 10/12/19
3. Adam	12/12/19 12/12/19	12/12/19 12/12/19	28/05/19 24/10/19 12/12/19	24/10/19 12/12/19		24/10/19		28/05/19 24/10/19 14/11/19 5/12/19 12/12/19 12/12/19		24/10/19 12/12/19 12/12/19	28/05/19 14/11/19 5/12/19 12/12/19
4. Olivia			11/12/19	11/12/19 12/12/19	11/12/19	11/12/19 12/12/19		7/8/19 11/12/19 12/12/19		11/12/19 12/12/19	
5. James			5/12/19 12/12/19	24/10/19 12/12/19		14/11/19	12/12/19	24/5/19 24/10/19 14/11/19 5/12/19 12/12/19 12/12/19		24/5/19 24/10/19 5/12/19 12/12/19 12/12/19	24/5/19 14/11/19 5/12/19 12/12/19
6. William		10/12/19	3/12/19	3/12/19 10/12/19		3/12/19 10/12/19		29/10/19 3/12/19 10/12/19		3/12/19 10/12/19	29/10/19 3/12/19 10/12/19

1

Key
Cycle 1 Cycle 2 Cycle 3

Indicators of Creativity Checklist cont.

Child's Name:	Creation (C)		Reflection and Evaluation (RE)			Overarching Social and Emotional Capabilities (SE)				
	Tries out new arrangements or approaches	Generates a solution to solve a problem	Reflects critically during the creating process	Reflects critically on idea and process for solving problem or constructing the product	Evaluates the product for its originality, effectiveness and being fit for purpose	Resilience: staying with the task even when struggling and learning from previous errors.	Self-determination: intrinsically motivated to solve a problem or complete a task	Collaboration: Playing and learning collaboratively with peers	Uniqueness: Being prepared to be different	Openness: Being receptive to novel ideas, imagination & fantasy
1. Ava	4/6/19 19/11/19	4/6/19 22/10/19	22/10/19 19/11/19	22/10/19	22/10/19 19/11/19	22/10/19 19/11/19	28/5/19 22/10/19 19/11/19	4/6/19 22/10/19 19/11/19		
2. Sarah	4/6/19 19/11/19 10/12/19	21/5/19 28/5/19 4/6/19 10/12/19	21/5/19 10/12/19	22/10/19 10/12/19	22/10/19 19/11/19 10/12/19	21/5/19 4/6/19 22/10/19 19/11/19 10/12/19	21/5/19 28/5/19 4/6/19 22/10/19 19/11/19 10/12/19	4/6/19 22/10/19 19/11/19 10/12/19	21/5/19 22/10/19 10/12/19	28/5/19 22/10/19 10/12/19
3. Adam	28/5/19 24/10/19 12/12/19	28/5/19 24/10/19	28/5/19 12/12/19 12/12/19		12/12/19 12/12/19	28/5/19 14/11/19 12/12/19	28/5/19 24/10/19 12/12/19 12/12/19	28/5/19 24/10/19 12/12/19 12/12/19		28/5/19 24/10/19
4. Olivia	7/8/19 11/12/19	7/8/19 11/12/19 12/12/19	11/12/19 12/12/19	11/12/19 12/12/19	11/12/19 12/12/19	11/12/19	7/8/19 11/12/19 12/12/19	12/12/19		11/12/19
5. James	24/5/19 24/10/19 14/11/19 5/12/19 12/12/19	24/5/19 24/10/19 5/12/19 12/12/19	14/11/19 12/12/19 12/12/19	14/11/19 12/12/19 12/12/19	12/12/19 12/12/19	14/11/19 12/12/19	24/5/19 24/10/19 14/11/19 12/12/19 12/12/19	24/10/19 12/12/19 12/12/19	24/10/19	24/10/19
6. William	29/10/19 3/12/19 10/12/19	3/12/19 10/12/19	3/12/19 10/12/19	3/12/19 10/12/19	3/12/19 10/12/19	3/12/19 10/12/19	29/10/19 3/12/19 10/12/19	10/12/19	10/12/19	29/10/19 10/12/19

2

B. Inquiry Questioning Models

Designing: Engineering a solution

Murcia, K., Clifford, E., Cross, E., Pepper, C., & Drury, S. (2020). Young Children's Inquiry: Questioning for science and mathematics learning connections in a construction project. *Teaching Science, 66*(4), 20-29. https://www.proquest.com/scholarly-journals/young-childrens-inquiry-questioning-science/docview/2569413012/se-2

PROBLEM Title: Sally Needs to Cross the River	
Overview	Establish a problem – Sally the doll needs to get across the river. Discuss modes of transport, how would we get across the Swan River? Look at some pictures of different types of boats. Draw possible designs. Allow children to explore a range of resources and materials we could use. Would paper/cardboard work? Discuss why you would need waterproof items. Test out objects to see whether they are waterproof. Create boat. Test it out. Does it move across the water? Does it float or sink? What happens when you put Sally in? Does Sally fit? Does it still float with Sally inside/on top? What do we need to change? Make changes and test it out again.
Materials/Resources What technology will children use or explore? Science Concept	Technology tools: scissors, sticky tape, stapler, glue. Measuring tools: tape measure, string, pop sticks Construction materials: paper, cardboard, plastic containers, sticks, pop sticks, string, fabric, balloons, straws, Styrofoam, elastic bands Chemical Sciences - Objects are made of materials that have observable properties Identify, describe and group objects/materials that have similar physical attributes Physical Sciences – The way objects move depends on a variety of factors, including their size and shape Manipulate objects and explore cause and effect on their movement
Where maths is used to help create a solution	Designing size and shape of boat. Measuring Sally, how tall is Sally? How wide is Sally? Does Sally fit?
Focus mathematical language	Measurement: units of (cm, mm, number of popsticks), bigger, smaller, wide, thin, tall, short Shapes: square, rectangle, circle, triangle, diamond Number: counting More, less
Activity Stages	**Inquiry Questioning**
Asking	How do people get around? How did you get here today? How would we get across the Swan River? How do people get across a river or lake or ocean? What can you make for Sally that will get her across this river?
Imagining	What will it look like? What shape will it be? What shape are boats? Can you draw it?
Creating	What material could you use? Could you use paper? Could you use cardboard? Why not? What does waterproof mean? Which items are waterproof?
Trying out	Does your boat float? Does Sally fit? Is it sturdy? Does the boat float with Sally inside? How can you make your boat move? How do boats move?
Improving	What do you need to change? What could make it better? What will make it float? What will make it move?
Reflecting	Did you make the boat like your original design? What did you change? How come?
Reasoning	Why didn't the first design work? Why did it work after you made the changes?

Designing: Engineering a solution

Murcia, K., Clifford, E., Cross, E., Pepper, C., & Drury, S. (2020). Young Children's Inquiry: Questioning for science and mathematics learning connections in a construction project. *Teaching Science, 66*(4), 20-29. https://www.proquest.com/scholarly-journals/young-childrens-inquiry-questioning-science/docview/2569413012/se-2

PROBLEM Title: How can the Three Billy Goats Gruff get across the river?	
Overview	Establish a problem – The Three Billy Goats Gruff need to get over the river to reach the green grass on the other side. How can they get across the river? What could we make? Look at pictures of bridges. Draw possible designs. Allow children to explore a range of resources and materials we could use. Talk about making the bridge sturdy enough so all three billy goats could cross together. Talk about
Materials/Resources What technology will children use or explore?	Technology tools: scissors, tape Construction materials: straws, popsticks, cups Story telling props: blue paper river, green artificial grass, three billy goats
Where maths is used to help create a solution	Size and shape of bridge, making sure the bridge is high, wide and long enough
Focus mathematical language	Measurement: units of (cm, mm, number of popsticks or straws), bigger, smaller, wide, thin, tall, short, long Shape: rectangle, curved, straight Number: counting More, less
Activity Stages	**Inquiry Questioning**
Asking	How can the Three Billy Goats Gruff get across the river to the green grass? How could we make a bridge? What do bridges look like? Are they straight or curved?
Imagining	What will it look like? What shape will it be? Can you draw it? Does it need to have legs to stabilise it?
Creating	Could we use straws or popsticks? How can we make sure it is sturdy and will hold the three billy goats?
Trying out	Is your bridge sturdy enough to hold the three billy goats?
Improving	What do you need to change? What would make it better? How can we make it stronger?
Reflecting	Did you make your bridge like your original design? What did you change? Why?
Reasoning	Why didn't the first design work? Why did it work after you made the changes?

C. Learning Stories

LS 1.1

Learning Story

Child's Name: Sarah	Cycle One
Date: twenty-first May 2019 (Time: 1:45 to 2:05pm)	Author/s Name: Chloe

Story (I See):
Sarah was playing at the playdough table with a peer. Her peer was making a birthday cake so she decided to make a birthday cake too. Her friend had used some pop sticks as candles but there were none left. Sarah said, "We don't need candles." Her friend said, "Are you putting this?" referring to the lids on the table. Sarah said, "Yeah I've got lots." Sarah then pushes the lid into the playdough. She pulls the playdough from around the lids, then pulls out the small circle shaped playdough. I then said, "What are you making here Sarah?" She replied, "Spots for my cake." Sarah made some more of the "spots" using the lids but gets to the fourth one and it breaks in half when she takes it out of the lid. She put it back squishing it down and tries to pull it out again. It breaks again. She tried again and on the third attempt the playdough comes out whole. Next, Sarah chooses a bigger lid and says, "I've got to make lots of spots. I'm making circles." I asked Sarah, "How many do you have?" She then counts using one-to-one correspondence from 1 to 7. She then tells me that it's going to be a purple cake while she uses the roller to flatten the big piece of playdough. Sarah then places the playdough circles on the top of the cake so I ask her, "What are the spots for?" Sarah says, "For the candles." I then asked her again to count how many candles and she used one-to-one correspondence counting 1 to 9.

Analysis (I Think):
Sarah wanted to make a cake like her friend but didn't have sticks to use as candles so instead she made candles using the playdough. I Think Sarah initially intended to use the playdough as candles as she said they were spots but as she went along making the spots she had an idea to use them as candles. This challenges other ideas and assumptions of what is usually used to represent candles on a pretend cake. Sarah has also made connections between things that are not usually connected and uses an object in a way other than its intended use, making playdough candles using bottle tops. She showed resilience to finish making her cake and learnt from previous errors when she continued to try and take out the playdough from inside the lid. Her product was original, effective and fit for purpose.

Where to next (I Wonder):
I Wonder what would have happened if Sarah used the engineering design process and drew her design first. Maybe she would have made the connection to use the circle pieces earlier or maybe she would have used something completely different, possibly just the lids?

LS 1.2

Learning Story

Child's Name: James	Cycle One
Date: 24th May 2019 (Time: 10:50am to 11:20am)	Author/s Name: Chloe

Story (I See):

I asked James if he could make something using anything he wanted in the room. He decided he wanted to do a drawing of a car. James starts off by making the wheels of the car. He draws two circles at the bottom of the page. He then draws the body and windows of the car. "It's actually a bus. It's a double decker bus," said James. James then draws the sky. He uses the blue Texta to draw a line at the top of the page and colours it in. I asked James "What could we do with your drawing of your car?" James says "I want to draw a rainbow in the sky, rainbows start with red." After James draws his rainbow, I ask him, "Now what could we do with your picture?" James pauses and thinks for a while. I then ask him, "Could we take your picture somewhere else in the room?" James then says, "I just want to draw my family." After James draws his family in the bus I say, "I have an idea, how can we make your double decker bus?" James replies, "By making craft." He goes over to the art trolley and selects crepe paper, two lids, a glue stick and scissors. James traces around the lid on top of the white crepe paper, then cuts out the circle. I ask James what he will do with the circle. He says, "Make another double decker bus." James goes and gets another piece of paper and uses the glue stick to glue the circle to the page. He then tries to trace around the lid again but then decides to draw it free hand. "I can draw it better than tracing," he says. After making the wheels, James starts to draw the body of the car. I ask him, "Do you think you can use something else instead of drawing the body of the car?" He pauses for a while thinking and then gets up, goes over to the art trolley and brings back a piece of black material, then says, "I'm just going to cut some material." He sticks it over his drawing of the body of the car. James then tries to make the windows using a black Texta and realises he can't see it on the black material. He gets up and goes back to the trolley and brings over a grey piece of fabric. He cuts the fabric into "tiny triangle windows" and does this four times. James has finished his collage.

Analysis (I Think):
James modifies his initial “design” and generates a solution to solve a problem, trying out a new arrangement/approach when he realises the black Texta over the windows cannot be seen so he uses grey fabric instead. James had an idea to make a car then he had another idea to change the car into a double decker bus. Also, James makes connections between things that are not usually connected and uses an object in a way other than its intended use, for example, he uses lids to trace the shape of the wheels onto crepe paper and uses material to make the bus, after some questioning by the practitioner researcher about using something instead of drawing.

Where to next (I Wonder):
It is interesting to see how James’s ideas changed from a car to a double decker bus whilst he was already drawing and the way he creates his picture on a whim. I Wonder if James was adding extra things e.g. the rainbow, to his pictures while he was thinking of something to do with the bus? I Wonder if he was going to use the lids as wheels but changed his mind as he took two lids from the art trolley but then only used one for tracing, making the wheels with the material. I Wonder if I could have used different questions to provoke James into creating a 3 dimensional version of the double decker bus. Next time I could give him a variety of resources to create with and ask him to make the double decker bus.

LS 1.3

Learning Story

Child's Name: Adam, Ava and Sarah	Cycle One
Date: 28th May 2019 (Time: 3:45pm to 4:15pm)	Author/s Name: Chloe

Story (I See):

I said to Adam, Ava and Sarah, "Let's make something, what could we make?" Adam suggested a mirror, a cat and a dog. While Sarah suggested a hand. I asked Ava if she had any ideas but she said no. Adam then suggested a tower. I asked how we could make the tower. Adam said, "We start with blocks." Ava repeated, "With blocks!" Adam said, "And stack them like this." He went over to the block shelf and chose the medium sized straight blocks and started to stack them one on top of the other. As the children were adding more blocks it started to wobble. "It's going to fall," said Adam. The block tower crashes to the ground and Adam says, "We need to build again." The second time round, Adam starts to build two columns side by side. Ava and Sarah help him out. After they used all the medium blocks they used the small blocks, keeping the tower the same size. Once all the small blocks were used they were finished. I asked them what other building they could make. Adam said "A circle." He gets 4 of the small curved blocks and made a circle with them. He builds it up to the next level and Ava and Sarah place the big S block on the top (see picture below). I ask them what the big S block is for. Sarah said, "It's a slide." She then changed her mind and said, "It's a charger. It lets everything get battery." I ask her why it needs to have a battery. She replies saying, "It's a light. It needs battery to work." Adam then says, "No it's not a light. When the bad guys come in, that thing stops the bad guy because it has jewellery." Sarah agrees. I then ask them what they need to do next. Adam says we need to make a satellite. I asked him what a satellite is. He says, "Satellite means a dangerous rocket." I ask the three children if they would like to look up satellites on the iPad. We had a look on Google Images for satellites and then watched a video on YouTube. After watching the video (https://www.youtube.com/watch?v=03pZdYVacaM) I asked the children, "What do satellites do?" Adam says, "They take photos of the earth." I ask them how we could make one. Adam says, "We need wings." Ava says, "Wings." Sarah says, "Camera." Adam says "We need an engine." I ask them what we could make it out of. Adam says blocks but Sarah says there's no more blocks. I then say, "If there's no more blocks, what else could we use?" Sarah says paper, Ava also says paper but Adam says Mobilo. So Sarah and Ava go over to the art table and begin drawing their satellites and Adam uses the Mobilo. He starts off with the yellow triangle piece and adds the rectangle and square pieces. He then makes the "wings" and connects it to the body. He tells me that the wings go on top and inside one of the small squares on the body is the camera. The girls draw similar pictures of an oval shape with a person inside and circles down the bottom (wheels).

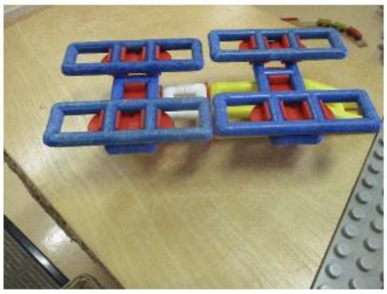
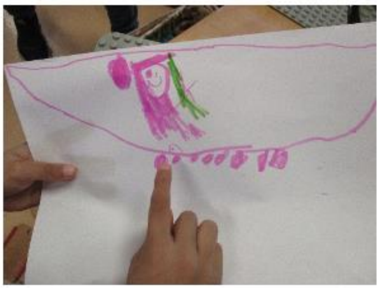











Analysis (I Think):

Adam had multiple ideas of what we could build, he contributed 6 ideas. Sarah suggested 2 ideas and Ava suggested none. Adam modified the initial design of his tower after the first one collapsed. Instead of one column like the first tower, he made the next one with two columns to add more support. In doing this, he also tried out a new arrangement/approach, shows resilience learning from previous errors and he must have reflected on his initial design deciding to change it the second time round. Adam also generated a solution to solve the problem of the tower falling. I Think Adam was leading this play, with Sarah supporting and Ava following along.

Where to next (I Wonder):
The ideas of building a tower and then a satellite were both Adam's ideas. Initially Adam thought a satellite was a dangerous rocket. With a rocket being a mode of transport, the planned activity for Cycle two ties into this and Adam could show an interest in this 'theme.' I Wonder if using the Inquiry Questioning Model will allow for more cohesiveness among the children's ideas and during the creating process. Will the children have more of a plan about what they're going to make rather than making it up as they go along and not just connecting/placing pieces without everyone understanding why once the Inquiry Questioning Model is introduced? I Wonder if having some questions planned using the Inquiry Questioning Model will help me to encourage higher order thinking resulting in an increase of creativity indicators?

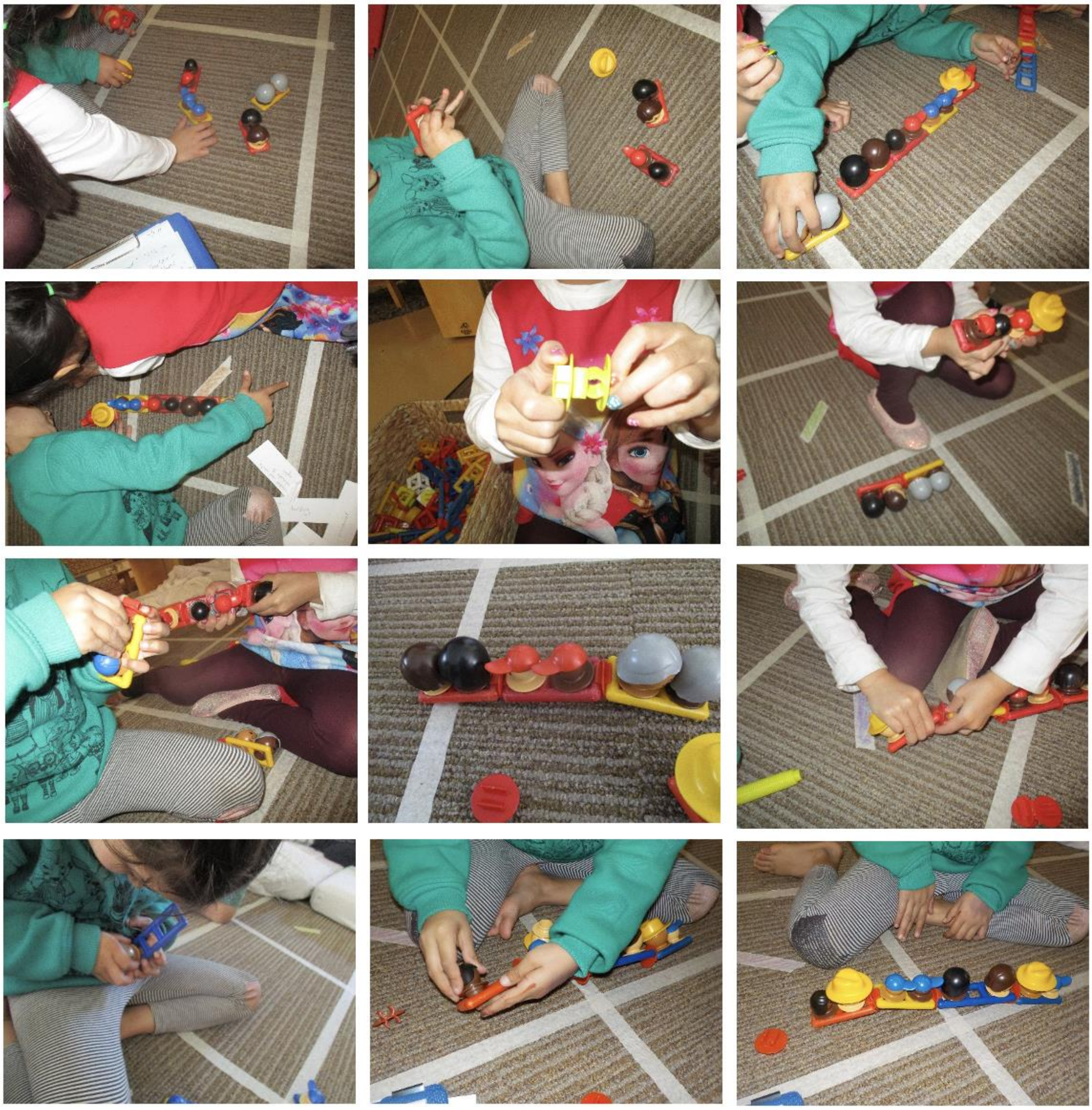
LS 1.4

Learning Story

Child's Name: Ava and Sarah	Cycle One
Date: 4th June 2019 (Time: 1:50pm to 2:10pm)	Author/s Name: Chloe

Story (I See):

Sarah was playing with the Mobilo on the mat. I asked her what she was making. She replied, "Something that moves on the ground. It's a train." In the Mobilo basket Sarah found some Mobilo heads that she tried to connect. She asked her friend Ava to help. Ava has a turn and says, "It's very hard you need to be strong." Sarah has another turn before asking me to help. I help them to push the head onto the Mobilo, where Sarah said she wanted it to go. Sarah then says, "I've got another choo, choo train." I ask if they're all little trains or if it's one big train. Sarah says it's one big train and starts to put them into a line like they're the carriages. I then ask her how she will make it move all together as one train. Sarah replies saying, "Nothing. They drive by themselves. It's just pretend." She then says, "You know how I make it move by itself? By pushing!" Sarah then pushes the trains from the back but the train doesn't stay together and starts to come apart. Sarah says, "It's broken the train." I ask her how she's going to fix it. She places it back together and tries again but it keeps breaking. I ask, "How can you make it so it doesn't keep breaking?" She says she doesn't know. I ask if Ava has any ideas. Ava says, "You can use those things." And shows us the connecting plugs. They try to attach the plugs but it's quite hard for them and Sarah says, "We're using our muscles but it won't work." Ava manages to connect them so Sarah continues to add people to new 'carriages' while Ava connects them on. Some of the plugs can connect 3 pieces and some can connect 2 pieces. The girls were using one that connects 3 pieces but they really only need one that connects 2 pieces. I ask them how many pieces they can connect on this plug and if it's better to use the plug that connects 2 or 3 pieces. Ava says 3 and Sarah says 2. Ava changes her mind and says, "Maybe 2 will work better." Together the girls say, "That works." Ava says, "We need the number 2 one." The train now has 4 'carriages.' Ava moves the train but it keeps breaking. Ava says, "I need help, no one's helping me." I ask her what's happening. She says it keeps breaking. I ask her why it keeps breaking. She says because it's too big (referring to the length of the train). Sarah goes and gets a longer piece of Mobilo. I ask her what she's got. She says a "long train." Ava then says, "I'm not doing it, I'm going to play in the home corner." She moves away from the play but Sarah continues. She manages to connect the Mobilo pieces together that she couldn't do before and says, "It's connected. I made it connected!" Sarah realises it's easier to connect the pieces first before adding the people. "I made my train!" she says.



Analysis (I Think):

Sarah could have used the magnetic trains and the train tracks to create a train but instead she wanted to use the Mobilo to make a train and use the people as the passengers. Therefore she is showing that she is making a connection between things that are not usually connected. Sarah shows determination, resilience and delayed gratification to make her train work even when it kept breaking. She got some help from her friend Ava but I Think as it was not Ava's initial idea to make the train she wasn't as invested in making it work and when the train kept breaking Ava went to play somewhere else. Both Ava and Sarah did however show that they could try out new arrangements, Ava switching from using the plug with 3 connection points to the one with two, and Sarah realising at the end it would be easier for her to connect the Mobilo pieces first and then add the heads on. They both had a purpose for their actions, putting the pieces together to make a train. Their goal was clear throughout the whole activity, however Sarah did change the initial 'design' from not connecting to having it connected as it kept breaking when she would move it from the back. In the end the design was original, effective and fit for purpose. Sarah did see her peer using the heads to place on the Mobilo, however she decided to make a train which no one had done yet also it did not break when moved from the front or the back. Ava suggested using the plugs to join the train together, proposing a possible solution.

Where to next (I Wonder):

During the next cycle the children will use a design process to solve the problem of getting a doll across a body of water. As Sarah and Ava made trains, a transport theme will tie in nicely and should hopefully engage them in the activity. I Wonder if implementing the design process would have made a difference to the outcome of what Sarah and Ava built today. Would Ava show more resilience if it were her own ideas and her own design?

LS 1.5

Learning Story

Child's Name: Olivia	Cycle One
Date: 7th August 2019 (Time: 10:45am to 10:52am)	Author/s Name: Chloe

Story (I See):

I asked Olivia if she could make something using the blocks, Mobilo or Duplo. She decided to use the Duplo blocks. I asked her what she is going to make. She replied, "a house." "We need a car to make a house, it can't be a house if we don't have a car," she said. I asked her, "Why not? Why do we have to have a car?" She replied, "So we can drive." I explained to her that some people don't have cars and that some people catch the bus or the train. Olivia then also added that people can also walk. However, Olivia wanted her house to have a spot for a car. I ask her what she is going to use to make her house. She pulls out of the basket an already made piece of wall with a hole for a door. Olivia says, "Because this has the door on it." She then chooses a cubed piece and decides to attach the wall piece to it. "This is the windows of the house," she says. Olivia uses some small pieces and puts them on top to secure the wall (door) to the cube (windows). She then decides to make the garage. "Need to make a garage for the car to park," she says. I then ask her, "Where does the garage go?" "Next to the house," she says. Olivia attaches some blocks to the end and uses her hand to measure how wide she needs to make the garage so the car will fit. She sees that with just those blocks it is not wide enough to fit one of the Duplo cars. "The car will poke out like that," Olivia says as she points with her finger. I ask her which car she will use, and she chooses her car. "So, you need to make sure it's big enough to fit that car," I tell her. "Let me see how wide we need it," Olivia says. Olivia puts the car in the spot for the garage and uses some Duplo to measure if the car would fit in width wise. "This is how wide," she says. I ask her how she's going to make it that wide. She says she will build it up using the blocks. Olivia thinks that it is too wide and decides to use a smaller block which will still allow the car to fit. "That's better," Olivia says. "That's just the right size for your car," I tell her. I ask her if there's enough room for the door to open to get in and out of the door. She says, "We won't put something here," referring to the other side of the garage deciding to not enclose the other side with a wall. Olivia finishes building up the back wall of the garage. "There we go," she says. "Now you've got your garage, but what does a garage need over the top?" I say. Olivia replies saying, "A roof." "So the rain doesn't come on the car and make it wet," she says. I ask her what she will use for a roof. "We can put that across," Olivia says referring to another 'wall' piece. "But how can we then attach this to it?" Olivia asks. "I don't know, how are you going to attach it onto there?" I say. The studs to attach another Duplo piece are on the wrong side to attach it horizontally, it will only attach vertically. I ask her if we can use that piece or if we need to use something else. Olivia says we need to use something else and decides to use the normal Duplo blocks. She places one next to the roof of the house and attaches a smaller one on top to connect the roof of the house with the block over the top of the garage. Olivia sees that it does not cover the car and that the "rain will still come on" the car so she adds another block to make the width of the roof as wide as the car and the back wall. Olivia pushes a bit too hard and the roof falls, "oops," she says. "That's okay we can still fix it," I say. Olivia fixes it and says, "There we go." "Does that cover all of the car?" I ask. "Yes it does," Olivia says but sees that the roof covers the car width wise but not length ways, "but we need to make it a bit more that way because then that part will poke out." She puts another two pieces underneath the top layer to lengthen the garage. "Does your house or car need anything else or is it finished now?" I ask her. "It's finished now," she says.

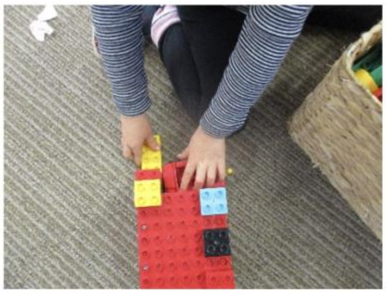
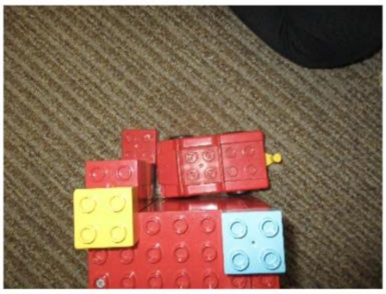
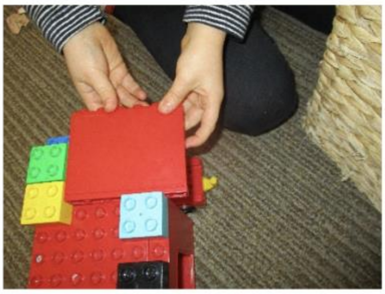
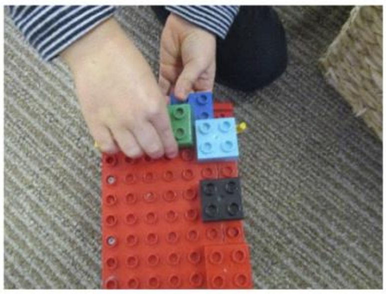
Analysis (I Think):

Olivia used some mathematic language in her play such as "wide" without any prompting from me. She uses non-standard units of measurement including her hand and the Duplo blocks. Olivia asked one question about attaching a piece of Duplo on as the roof. She had one idea to make a house with a garage and was self-determined to finish making her house and garage. Olivia generated a solution to her problem and tried out a new arrangement when she was making the roof using a piece that would not attach, she instead used the normal Duplo blocks. Olivia also showed that she had a purpose for her actions, creating her house and garage using the Duplo blocks.

Where to next (I Wonder):

Olivia asked me a question, "But how can we attach this?" referring to the piece she was going to originally use as the roof for the garage. I asked her if that piece can be used or if she needs another piece. Maybe this prompted her to change her mind about this piece and use something else. I Wonder if I could have prompted her in another way and if she could have figured out a way to use that piece, possibly using something else in the room that is not Duplo? She may have then used an object in a way other than its intended use. As Olivia created a house but was more focused on making the garage for the car, I Wonder if she will show an interest in making a boat in the next cycle of action?





LS 1.6

Learning Story

Child's Name: William	Cycle One
Date: 29th October 2019, Time: 3:00pm to 3:25pm	Author/s Name: Chloe

Story (I See):

I asked William, "Using the things in the room, can you make me something? What would you like to use?" William said, "Blocks." William went and took a large wooden block off the shelf. He placed it on the ground and went to get another. "What are you building William?" I asked him. He replied saying, "A spikey dinosaur." William continued to build with the large blocks and then took some smaller blocks, placing them upright on top of the large blocks. I ask William, "What are those bits you're putting on there?" "The spikes. Now I'm going to put the head on," William replies. He takes another long block and places it next to the body of his dinosaur and says, "Done." I ask him if that is the head and he says yes. I then ask him, "What shape is a dinosaur head usually?" "A circle, but we don't have any circle" he replies. So I ask him, "What could you use instead?" William suggests another long object. "Is there anything else in the room we could use as a circle? Or are there other blocks we could use that could make a circle?" I ask. William takes two small curved blocks off the shelf and says, "These?" I ask him how many he would need to make a circle. "Uhh, two," he says. "Let's have a look," I say as William places them on the ground making a semi-circle. "One more," he says. "Actually, I need one more," William says. "How many of those curved blocks make a circle?" William counts each block using one-to-one correspondence "1, 2, 3, 4," he says *(Figure 1.)*. I asked William if his dinosaur has a long or short neck and we discussed how he will make the other features of his dinosaur. "How many fins does your dinosaur have?" I asked. "1, 2, 3, 4" counted William using 1 to 1 correspondence *(Figure 2.)*. William's finished underwater dinosaur had 2 legs, 4 fins, a body and a head. He didn't want to add anything more onto his dinosaur *(Figure 3.)*. I then asked him, "Do you think you could make your spikey underwater dinosaur out of anything else in the room? William decided to make a different dinosaur. "Are you still going to use the blocks or is there anything else in the room that you might use?" I ask. "Still using these blocks. Now I'm finished, it's a tyrannosaurus rex," said William as he changed his dinosaur to a T-Rex by adding smaller blocks for the arms and removing the spikes *(Figure 4.)* William then decided to make a long neck dinosaur. He made the body and legs using long blocks and then put a big block over the legs like an "X marks the spot" to make the arms. Next William added 4 spikes to the top of the dinosaur's body *(Figure 5.)*. Lastly, William added the head using 4 small, curved blocks. William then said his T-Rex's arms and legs was an X marks the spot but the treasure is the dinosaur and that it was a scary, golden dinosaur that was invisible. Once he was finished, I said to William, "maybe we can make dinosaurs out of something else." After pausing and waiting for a response, William said nothing so I then said, "Do you think maybe we could make dinosaurs out of the Mobilo or Duplo?" "Mhmm… Lego!" said William. We moved over to the Lego basket. "What kind of dinosaur are you going to make?" I asked. "A T-Rex," said William. "So how do you make the legs if they're not sticking?" Asked William trying to attach two pieces of Duplo Lego together lengthways. He figured out he could stagger them to look like stairs, “Wait I can make stairs,” he said *(Figure 6.)*. “How else could you make the legs of the T-Rex?” I ask. “Long, but these are long,” said William. “And the head can be, then.. like this, two legs,” said William. He then made the arms using two small Duplo blocks and then chose a long bridge piece for the tail *(Figure 7)*. William then decided to make the other dinosaur he made using the blocks, this time using the Duplo Lego. First he chose a square Lego block for the head, then the long neck by stacking 4 square Lego blocks. Next he added the legs as two rectangular Lego blocks under the neck and then two square Lego blocks as arms on top of the rectangle ones. “Hold on, would they have arms? The long neck dinosaurs?” I asked. “No,” said William. “How many legs does it have,” I ask. “Lots,” said William. “How many?” I ask. William went to count, “1, 2, 3, 4,” he said counting using one-to-one correspondence. Lastly William added the tail on the back using a rectangle piece *(Figure 8.)*. William then put the Lego T-Rex with the T-Rex he made using the blocks *(Figure 9.)*. He then put the Lego long neck dinosaur with the long neck dinosaur he made using the blocks *(Figure 10.)*.

Analysis (I Think):

William is self-determined to finish his dinosaurs using the blocks and then the Lego. He maintained interest as it was something he wanted to build and had a purpose for his actions. William modified the original design of his first dinosaur, turning it into a T-Rex by removing the spikes and changing the arms to the smaller cylinder blocks. William’s dinosaurs were original and they were effective and fit for purpose in the sense that they resembled dinosaurs.

Where to next (I Wonder):

I Wonder if William will demonstrate more creativity indicators after introducing the Inquiry Questioning Model/engineering design process. As Willliam was a late addition to the study, Cycle two had already commenced around the topic of transportation. Based on this activity he demonstrates an interest in dinosaurs, I Wonder if William will show interest in the activities in cycles 2 and 3.

Figure 1.

Figure 2.

Figure 3.

Figure 4.

Figure 5.

Figure 6.

Figure 7.

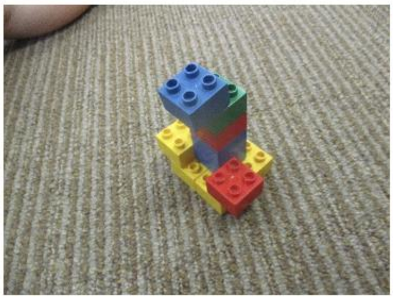


Figure 8.

Figure 9.

Figure 10.

LS 2.1

Learning Story

Child's Name: Ava and Sarah	Cycle Two
Date: 22nd Oct 2019 (Time: 2:10 – 2:55pm)	Author/s Name: Chloe

Story (I See):

I introduced Sally the doll to the children and asked how she could get across the water trough which represented a river. Sarah said, "could go around." I mentioned that the river is very big and it would take a long time to go around. Ava said, "a boat." I showed the children different types of boats and Ava talked about going on one of the boats I showed them. We discussed some boats needing oars to move it and some boats having sails. Sarah said the sails were flags that make the boat pretty but when I told her they were called sails to make the boat move and asked what pushes the boat along, she replied saying "the wind and it blows big and the boat goes and floats." We then looked at pictures of boats with engines. Sarah decided to make her boat like the ferry type boat, counting 4 windows in her picture (*Figure 1*) and Ava decided to make hers a paddle boat with 2 oars (*Figure 2*). The children then used the pictures to draw their designs and we discussed what materials we could use to make the boats. Ava said wood and Sarah said paper. I asked if the paper could go in the water. Ava said, "No it will rip." Sarah then said, "I know, bricks!" I asked if the bricks would float on the water or sink to the bottom and Ava said they would be "Too heavy and sink." We went inside and looked at the different materials I had collected. The children collected a number of plastic containers of different sizes, some straws, pop sticks, string, sticky tape and masking tape. We discussed size and making sure Sally would fit and used the measuring tape to measure how long Sally was. Sarah read the tape measure as "20" and "9." I told them that Sally is 29cm tall. We then measured how wide Sally was. At first Sarah said 33 and Ava repeated 33. When I told them it was one of those "tricky teen numbers" they paused to think and Sarah then said "13!" The children both said they need to measure how long their containers were. "Too short," Ava said about one container. They then used trial and error, using Sally the doll to see if she would fit in the containers (*Figure 3*). Ava used two of the slurpy straws to make oars for her boat, sticking them on with sticky tape. Her boat that she made looked like her original design. Sarah decided to make her windows using masking tape on the container and drawing on them. She decided she wanted to change her design and add a sail. Sarah went and found some felt on the art trolley and tried to stick it directly onto her container. I asked her, "Which way does the sail go on the water? Would it go that way or a different way?" Ava said, like this and showed the felt on a stick. 'Does it go sideways like the oars or does it go up?" I asked. Ava replied, "Sideways." I showed Sarah a picture of a boat with a sail and asked, "How would the wind catch it?" Sarah cut the felt into a square, she wrapped it around a stick. "Have a look, is this one wrapped around?" I said pointing to the picture of a sail. "I want to wrap mine around," said Sarah. "You can't wrap around," said Ava. "Will the wind catch it if it's wrapped around?" I asked. "Will it? Tell me?" said Sarah. "What do you think?" I asked Sarah. "Let's just try," said Sarah. Sarah continued to wrap the felt around the stick. I then asked, "What shape is your boat Ava?" "Square." "Is it a square? Are all the sides the same?" "No. Rectangle"

“Sarah, what shape is your boat?” “Square” “You’ve got a square one.” Ava then said she knew what to do to make a sail and showed Sarah that she could put the felt piece at the top end of the stick and attach it with sticky tape (*Figure 4*). “Like a flag,” I said. “That’s a great idea,” said Sarah. Sarah sticky taped the sail onto her boat. We filled up the trough and tested the boats out in the water. Sally tipped backwards into the water. Ava said, “No. Her head.” “What’s wrong with her head,” I asked. “Her head keeps falling down,” said Ava. We tried a few times but she kept falling in (*Figure 5*). “Did it work Ava?” “No,” she said. Sarah had her turn and Sally also fell out of her boat (*Figure 6*). “What do you think we need to do?” I asked. “I Think we need to make it bigger,” said Sarah. As we had run out of time, I told the children that we can revisit it to make it bigger another time.

Figure 1

Figure 2

Figure 3

Figure 4

Figure 5

Figure 6

Analysis (I Think):

Sarah modified her initial design, adding a flag. Both Sarah and Ava used the materials in ways other than their intended use. Sarah used a plastic container to make the base of the boat, a stick and felt as the sail and made windows for decoration using masking tape. Ava also used a plastic container as the base of the boat and spoon straws as oars. Ava showed more resilience in this activity participating the entire time and offering help and advice to Sarah. She was able to generate a solution to solve the problem Sarah faced with making her sail. Sarah generated a solution to the problem of Sally the doll tipping over into the water, suggesting they need to make bigger boats, reflecting and evaluating on the finished product. Both children had a purpose for their actions, designing and creating boats. Some mathematic concepts explored such as measuring, number, shape/geometry and counting. Sarah was able to read the number 29 and correct herself with some scaffolding to read 13. She also counted 4 windows in her drawing and on her boat and could tell me that her boat was shaped like a square. Ava said her boat was shaped like a rectangle.

Where to next (I Wonder):

Instead of saying to Sarah “Which way does the sail go on the water?” when she was attaching her sail horizontally to the boat, I should have said, “How does a sail attach onto a boat?” I need to keep my language in mind when questioning. Will making the boat bigger make Sally not fall out? I Wonder if in the next lesson, the children will achieve more of the indicators of creativity from the checklist? Would it be better to first explore the materials we have on hand and draw our design from that? Would that limit creativity?

LS 2.2

Learning Story

Child's Name: Ava and Sarah	Cycle Two
Date: 19th Nov 2019 (Time: 11:00 – 11:30am)	Author/s Name: Chloe

Story (I See):

We recapped what happened the last time we made a boat for Sally, she sank. I asked the children, "What do we need to do to make Sally float?" "We need a bigger one," said Sarah. "Make it heavy," said Ava. "What would happen if you made it heavy?" I asked. Both children said, "Float." "If it's too heavy it will sink," Sarah then said. She then asked me if one of the containers was heavy. I asked her what she thought. "Heavy," she said. We compared it to Sarah's original boat by hefting and decided it was heavier. Sarah chose a container that was smaller but deeper than the original boat she made. We tested to see if Sally would fit inside and she did. Sarah then tested it out. Ava chose a container with holes underneath. I asked what would happen with the holes. "The water will come in," said Sarah. Sarah suggested covering them with sticky tape. We looked at the original designs the children drew. I asked them if they would make their boats using the same designs. "Maybe, not," said Ava. I suggested we go and test out some of the containers with Sally inside to see if they would float. We found that Sally would tip backwards in the containers in the same way she did the last time they made their boats (*Figure 1)*. After looking at all the containers, I asked the children if they thought the containers were too small or if they were the right fit to make a boat for Sally. Ava said, "Too small." "What would happen if we made a big boat for Sally?" "Yeah!" said Ava. "A cruise ship," said Adam who was watching Sarah and Ava making their boats. Sarah suggested that her and Ava put their boats together to make a bigger boat. Ava suggested putting oars on like on her original boat. I asked the children how they would stick the containers together. Sarah said, "Sticky tape." Then I asked them how they would set out the containers so it would be big enough for Sally to float. Sarah said they will use sticky tape so I asked her to show me how. They decided to make different rooms for Sally on her boat. "Do you think Sally would sink this?" I asked referring to one of the containers. "Nah... because she's got a little space to sit," said Sarah. "Do you think it would be better if she sat down or lay down?" I asked. "Lie down," said Sarah *(Figure 2)*. Sarah attached two containers together, making the boat long. "I Think I'll make it long," she said (*Figure 3).* I then asked Ava where her container should go. "Do you think it needs to go here to make it longer or do you think we need to put it here to make it wider?" I asked the children. "Wider," said Ava. Ava put the container on the left side and Sarah helped her to sticky tape it to the rest of the boat (*Figure 4).* "I have to stick the oars on too," said Ava. Ava had another container, "Where is that going to go? Is it to make it longer or wider?" I asked. "Wide but this side has the oar that's why I put it here," Ava said putting the container at the end of the boat making it longer *(Figure 5)*. Ava then added another container onto the end so the boat would be four containers long with one container attached to the left side of the first container (*Figure 6)*. "I'm making the T.V." said Ava adding another container on top of the third container *(Figure 7).* I asked the children which container Sally would lay in. Sarah decided the first container they chose. They took the boat to the water trough to test it out to see whether this time Sally would float in the boat. First Sarah lay Sally with her head at the top of the boat but she tipped in the water again *(Figure 8).* The children thought that the boat wouldn't be able to hold Sally. I asked what would happen if they placed Sally in a different container. Sarah turned Sally around in the same container *(Figure 9)* and Sally was able to stay inside the boat and float *(Figure 10).* Afterwards, we returned to the table to debrief. "Sarah and Ava, did you make your boat like your original design?" I asked. "No," they both said. "How is it different to your original design?" I asked. "Because we attach it very big," said Ava. I then asked why their original design didn't work. "Because it wasn't big enough," said Ava. "Did it work after you made the changes and made it bigger?" "Yeah," they both said.

Analysis (I Think):

Sarah reflects critically about Ava's idea to make the boat heavier. At first she agrees that the boat would float if it was made heavier but after thinking about it she changes her mind. Sarah's solution is to make the boat bigger, Ava's is to make it heavier. Sarah is trying out a new arrangement and approach to the original design, looking at the weight of the container. Sarah first thought that a heavier boat would float then after some reflection decided it would sink. Sarah and Ava are collaborating, sharing ideas and opinions about how they will make their boat float this time. The children try a new approach, putting their boats together to make one big boat. The children are putting the boats together to make a bigger boat, modifying their initial design. Their solution to their problem of the boats sinking is to make one big boat. Staying with the task and learning from previous mistakes. The children are motivated to make their boat float with Sally in it. The children collaborate and learn from one another to make one big boat. Sarah and Ava evaluate whether their new boat floats and if it was different to their original designs. Ava is able to explain how it is different and why the first design didn't work. After their first boats sank, both Ava and Sarah still stayed with the task, changing their design so it would work. Both children were intrinsically motivated as it was an activity of interest to them both.

Where to next (I Wonder):

As the children have completed Cycle two we will move onto Cycle three and introduce the next problem, how to get the 3 Billy Goats Gruff across to the other side of the river.

Figure 1

Figure 2

Figure 3

Figure 4

Figure 5

Figure 6

Figure 7

Figure 8

Figure 9

Figure 10

LS 2.3

Learning Story

Child's Name: Adam and James	Cycle Two
Date: 24th October 2019 (Time: 11:20am to 12:20pm)	Author/s Name: Chloe

Story (I See):

I introduced Sally the doll to Adam and James and the problem of Sally getting across the river. "She's stuck," said Adam. I showed the children a photo of the swan river and asked if they've seen it before. James replied, "That's the Swan River." I then asked how we could get Sally across the Swan River. "With a boat," James said. "No she could jump, put a little trampoline there and then she could jump on the other side" said Adam. "Do you think she would go far enough?" I asked. "No," said James. "The Swan River is very big isn't it, could we put a trampoline on the shore of the Swan River and jump and go to the city? The children shook their heads. "What would we need to do?" I asked. "We'd need to get a speed boat," said Adam. I showed the children some pictures of different types of boats. They named the different types of boats I showed them. A cruise ship, sailing boat, speed boat, jet boat and a cruise boat. We collected some paper and pencils and I asked the children if they could draw a picture of the boat they would make for Sally, but before drawing we talked about how the boats move. James said the speed boat moves with a jet engine and with a steering wheel, while the sailing boat moves with wind. The children then talked about a TV show they watched with different boats on it including a sailing boat which had sails. I then showed the children a photo of a paddle boat and asked how it moves. "Swimming, no persons," said Adam. "How do they make the boat move?" I asked. "With these," said James pointing to the oars. I asked what they're called. "Paddles," said Adam. "Or oars," I added. "What kind of boat would you make for Sally to get across the river? Do you think you'd make one with oars?" I asked. "We'd have to make a speed boat so she could get there fast," said Adam. We looked at the picture of a speed boat. Adam said, "I can't make a speed boat, I can't draw one." "Can you draw one 'cause I'm very bad a drawing?" He asked. I told him, "You're good at drawing" and then said, "Have a try, have a look at this boat and look at the shape of the boat. What kind of shape is this?" Adam continued to say he was bad at drawing. "James is going to have a try," I said. I asked him about the shapes and lines on the boat and whether his will have windows. "It's a two layer boat," said James. "Do you mean a two storey boat?" I asked. "Mhm,"said James. "Chloe, that is a parallelogram," said Adam. "Can you draw a parallelogram?" I asked. "It's tricky," he said. "It is tricky, but I Think you can do it," I told him. Meanwhile James had started his drawing of the boat. "Got two windows?" I ask. "That's not even a window," said James. "What is it?" I asked. "Don't know," he said. "Is it where the wheel goes?" I asked. "No, it's a hatch." He said about what he drew at the front of the boat. The other square being a window (*Figure 1*). Adam had a try at drawing his boat, drawing two rectangles. The top rectangle being the container and the bottom being some Styrofoam pieces (*Figure 2.*) I showed the children the materials I had collected for them to use to make their boat. The children picked some things they wanted to use. I said to them, "Have a look at your drawing of your boat, and looking at these things that you want to use for your boat, do you think you need to change your drawing?" They shook their heads. Adam asked why there were measuring tapes. I told him that we need to make sure Sally will fit in our boats so we can use the measuring tape to measure her and the boats. We looked at different containers to see if Sally would fit and the different materials. Adam tested to see if Sally would fit in his container by putting her inside. I then asked him, "If we put this on the water do you think it would float?" "Yes," Adam replied. I then asked, "What would happen if we were to put a cardboard box in the water?" Adam said it would sink, but James said it would float. "What happens if you put paper in the water?" I asked. "It will sink," said Adam. "It won't sink, it will get wet," said James. "And then it will sink down, down deep," said Adam. I then asked, "So what do you think will happen if you put the cardboard box in the water?" "It will rip," said James. "Do you think this material is better? The plastic?" I asked the children. "Yeah," said James. Adam asked if we could test out the cardboard box and the plastic container to see what happens. James wanted to make his boat first and then test it after. Adam then changed his mind and decided to make it first like James. The boys then set to work, creating their boats for Sally. James wanted to make a sail. He decided to use a stapler to connect the slurpy straws to his container and cut out paper triangles to make the sails (*Figure 3*). "Do you think Sally is going to fit in your boat James?" I asked. He tested to see if Sally would fit but she couldn't with the sails in the middle. "She can't," he said. "What could you do?" I asked. "Make a bigger boat?" James replied. "Using that," he said referring to the juice container. He tried to cut the top off. "It's hard isn't it?" I said. "What do you need to do, you think?" "Need sharper scissors," James replied. We found some sharper scissors and James successfully cut off the top of the container (*Figure 4*). Meanwhile Adam wanted to attach the Styrofoam pieces to the bottom of his container using the glue. I said to him that it might take a while to dry but he still wanted to test it out today. He decided to use a glue stick. "This glue's not strong for this," he said. "What glue could you use?" I asked. "I know, this glue," he said referring to the PVA glue. After Adam glued the Styrofoam to the bottom of the container he was finished making his boat (*Figure 5*).

After cutting off the top of the juice container, I asked James, "Now what are we going to do? Is Sally going to go in that?" "Yeah," he said. "How are you going to put Sally in there?" I asked. James tested out putting Sally in the container (*Figure 6*). She didn't fit all the way in. "Maybe upside down," James said trying to put Sally in the container head first but she still didn't fit. "She doesn't even fit in," he said. "She fits in doesn't she," I said, "But she's not what?" James replied, "Long enough?" "She's too long, isn't she?" I said. "What else could you do James?" "I don't know, I could put that somewhere on this," he said referring to putting the juice container on the original boat with the sails but it didn't fit. He then said he could use a small water bottle underneath and add some salt and vinegar to make it move. "We can use this whole bottle to go like that and we can put all the stuff to go out of it then it will blast out of here and you put it in the water, take the lid off then the boat will go blasting," James said. "What are you going to put in the bottle?" I asked. "Salt and Vinegar," he replied. "I need salt and vinegar too," Adam said. "And that's going to make it move?" I asked. "Yeah you put it in there and put it underwater and take off the lid,' said James. "Oh we might have to try that. We'll have to get some. What happens when you put salt and vinegar together?" I said. "They make combustion," said James. "Do you think it might be something else that you put with the vinegar? Something that we may have used before to make a volcano?" I asked. "Flour?" James asked. "It's similar to flour," I replied. "Sugar?" Adam asked. "Bicarb-soda," I told them. "Yeah," said James. I asked James who's idea it was to add bicarbonate soda to vinegar to make something move. James said his dad. I told the boys that we will make the boats first and then can try James' idea. Adam's boat was still drying but he still wanted to test if

Sally will float in a container so he chose one to test out while waiting till the next day for his boat to dry. As we were running out of time we took the boats to test. James wanted to use his original boat with the sails. He managed to get Sally to sit with the sails in between her legs but she was too top heavy and fell backwards into the water (*Figure 7*). Adam's container that he wanted to test while his boat was drying also sunk when he put Sally into it (*Figure 8*). After testing I asked the boys if it worked, they said no.

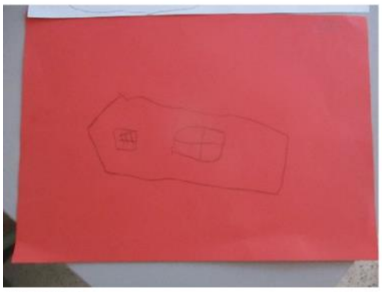


Figure 1.

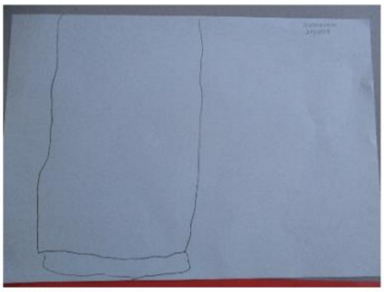


Figure 2.

Figure 3.

Figure 4.

Figure 5.

Figure 6.

Figure 7.

Figure 8.

Analysis (I Think):
Adam had two ideas of how to get Sally across the river. At first he suggested that Sally jump from a trampoline, making a connection between trampolines and crossing rivers, which isn't a usual connection to make. When I said the river is very big he then suggested a speed boat after reflecting critically on his original idea. Adam wasn't confident drawing his design and felt that he isn't "good" at drawing after some gentle persuasion and watching his peer (James) he finally decided to draw a design. To try and help him without doing it for him, I asked him to look at the picture and at the shape of the boat he wanted to make. Adam was then able to tell me he could see a parallelogram. Talking about the shapes in the picture was a great way to incorporate a mathematic concept. Both boys showed self-determination to draw and then make their boats. James was also determined to cut the top off of the juice container and Adam to test Sally in anything that day. I Think this shows that both boys were interested in the experience. Both boys used objects in a way other than its intended use, using the plastic containers, styrofoam and

slurpy straws to create a boat, another use for the objects. They both also reflected on what type of material to use, if cardboard would work and if it would float or sink through some prompting by myself. James generated a solution to solve the problem of Sally not fitting in his boat, he made her sit with the sails between her legs, however she was too top heavy and fell backwards. Before coming to this solution, he tried another arrangement of making the boat bigger cutting the top off a juice container but when he tested to see if Sally would fit, she was too big so he went with his initial design. Adam generated a solution and tried out a new arrangement to stick down his Styrofoam pieces on the bottom of his boat. The glue stick was not sticking so he decided to use PVA glue but needed to wait for it to dry. He didn't show delayed gratification as he wanted to test it out that day and the glue didn't hold. Both Adam and James had a purpose for their actions, using the resources to make a boat for Sally to get across the water.

Where to next (I Wonder):
Next session we will review what happened today, why it didn't work, what we can do to change it. I Wonder if the boys will manage to make their boat so it will float. Will they decide to make it bigger and lay Sally down so she doesn't get top heavy? Will they try to make their boat move if we have enough time to revisit after making it float? I Wonder if I show the children the materials before their drawing, if it would make a difference and they will be able to stick to their original designs?

LS 2.4

Learning Story

Child's Name: Adam and James	Cycle Two
Date: 14th November 2019 (Time: 11:05am to 11:40am)	Author/s Name: Chloe

Story (I See):

We started off the session by looking at the original designs Adam and James made in the last session. "Do we need to make a new design," I asked. "Yes," said Adam. "Why do you think we need to make a new design, what happened last time?" I asked. "Sally sunk," said Adam. I then asked, "How can we change our design so Sally won't sink the boat? "A bigger container," suggested James. "Yeah," agreed Adam. The boys looked through the collection of containers. "What kind of boat do we need to make now?" I asked. "I know, a jet boat," said James. James showed Adam a photo of a jet boat from the photos I had printed out *(Figure 1.)*. The boys continued to look through the materials provided. Adam remembered the bicarbonate soda and vinegar idea and wanted to try it out. The boys continued to look at the different containers. "I suggested the boys make one big boat together. "Let's do teamwork," Adam said. James lined up two of the plastic container trays. "So do you think making it longer will work?" I asked *(Figure 2.)*. "She can lie down in here (one of the containers) and I can make stuff to be here (the other container)," said James. "You don't think she's going to sink it?" I asked. "Actually she is 'cause one side is light and the other side is heavier," said James. I asked James, "So where would Sally need to go then?" "Here," James said point to the middle of the containers. I asked if Sally would fit. James went to get Sally from the home corner to check. "Do you think Sally needs to be sitting or do you think she needs to be lying down?" I asked. "Sitting. Lying down," said Adam. James said sitting on one side or lying down on the other. I reminded James that he told me that if we were to put Sally on the side that she would tip over and asked if they could add anything else to their boat, could they use something else as well. Adam said, "Connect all the pieces to make a cruise ship." "We need to put those there," said James putting Styrofoam pieces underneath the containers. I asked why he needed to put them on the bottom, "So it would be flat," said James. "Do you think that would help it to float?" I asked. "Yes, because it be more floatable," said James *(Figure 3.)*. "Hey, we could connect our boats," said Adam. "To make it go bigger… and we could use this to go there so Sally won't fall off." We put Sally laying down on one side of the containers *(Figure 4.)*. I said to James, "Remember you told me…" and James replied, "she's going to tip." "So what can you put on there so Sally won't tip?" I asked. "Mmm something heavy on that side, that's the same weight as Sally" said James pointing to the empty container next to Sally. "Ok. What could we get that would be the same weight as Sally?" I asked. "We could get a scale and put Sally on to see how heavy she is and we could get something to see how heavy that is to see if it's the same size as Sally," said James. We explored what the boys could put next to Sally and decided to use another doll. "There's another doll the same as Sally but with different clothes on," said James. "I got one," said James." Is it the same as Sally," I asked. "Look Chloe, there's twin Sally's," said Adam. The other doll was slightly bigger and James was able to tell me it was bigger when I asked if it was bigger or smaller. "Do you think it will work if we put both of them in?" I asked. James was thinking and put the doll in the container *(Figure 5.)* The boys then drew their designs based on what they had planned with the materials. James drew 6 squares down the bottom to represent the 6 pieces of Styrofoam underneath the boat (*Figure 6.)*. He drew a top view and bottom view *(Figure 7.)*. Adam drew the two containers and the Styrofoam as one rectangle on the bottom *(Figure 8.).* The boys start to make their boat by gluing down the Styrofoam to the containers. "We actually just need two," said James, referring to the number of Styrofoam pieces *(Figure 9.)*. As we were running out of time and needed to wait for the glue to dry the boys did not get a chance to connect the two containers together. I put their work in progress in a safe place for the next session.

Analysis (I Think):
Both Adam and James modified their initial designs as the original design did not work. James proposed a possible solution to solve the problem of Sally tipping, putting something on the other side that is the same weight as Sally. He ended up choosing a doll that was similar in size to Sally just a bit bigger. At first, James had the containers length ways but tried out a new arrangement, putting them side by side. Both children had a purpose for their actions, they picked out the materials they wanted to use and designed a new boat for Sally to float. James showed resilience, learning from the last session where Sally tipped into the water, and reflecting on his ideas and during the creating process. He decided this time to make the boat bigger, placing two containers side by side, one for Sally and the other for another doll to counterbalance the boat so it would float. James showed self-determination by completing another session, he started to get a little uninterested in the middle of the session but managed to finish off enthusiastically. Adam seemed to be more of an onlooker during this session.

Where to next (I Wonder): In the next session, the children will need to finish off creating their boat and test it out. I Wonder if it will float this time being bigger and having another object to counterbalance Sally. I Wonder if the children will still be interested in completing the activity.

Figure 1.

Figure 2.

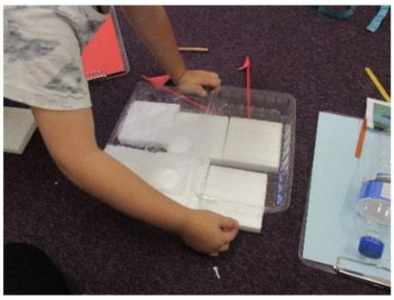


Figure 3.

Figure 4.

Figure 5.

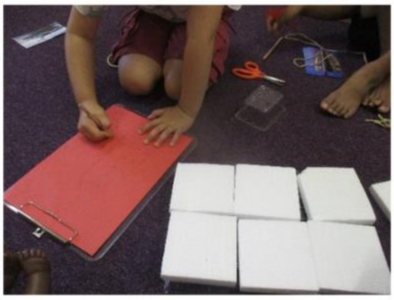


Figure 6.

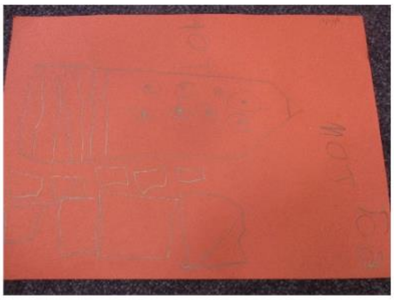


Figure 7.

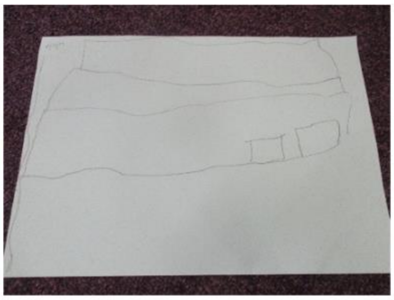


Figure 8.

Figure 9.

LS 2.5

Learning Story

Child's Name: Adam and James	Cycle Two
Date: 5th December 2019 (Time: 11:00am - 11:30am, 2:00pm)	Author/s Name: Chloe

Story (I See):

We recapped what had happened in the last two sessions of Cycle two, where Adam and James' boats sunk with Sally inside and they designed and begun to make a new, bigger boat. I got out their two containers that they had glued Styrofoam pieces underneath. James placed them side by side and said, "We need to put sticky tape on the top and the bottom." "Would it better to put sticky tape on the bottom or the top first?" I asked. "On the top," said James. James attached the two containers together using sticky tape *(Figure 1.)*. I then asked the children, "Do you think Sally will float in your boat or sink?" "Sink," replied James. "What should we do so Sally doesn't sink?" I asked. "Make it a cruise ship," said Adam. "How?" I asked. "By putting lots and lots more layers on," said James. James turned the boat over and grabbed another container with two compartments and put it on top *(Figure 2.)*. I ask the boys, "Where is Sally going to sit?" James replied, "In the middle?" "Would she be comfortable in the middle?" I asked. "No," said James. "What do we need to put in it?" I asked. "Cushions," said James. "How will we make it?" I asked. Adam picks up some Styrofoam and starts sticking it inside the container. "I'm making a bed," he said *(Figure 3.)*. James picked up a bottle and started cutting. "What are you doing?" I asked him. "We need to put something heavy in there so it will float," said James. "What could you put in there?" I asked. "A weighting ball that's not very heavy," said James *(Figure 4.)*. Adam also got a bottle and said, "I need water in here." James suggested, "we could put water in there to weigh it." Adam went to the bathroom and filled up the bottle with water *(Figure 5.)*. The children sticky taped it onto the right side of the left container *(Figure 6.*). We then went outside to test the boat and see if it would float with Sally inside but it sunk, splitting in the middle *(Figure 7.)*. Adam suggested more sticky tape. James suggested taking the water bottle off but I asked what would happen to Sally without the water bottle. "It will be heavy on this side and light on this side," said James. "What do we need to do then?" I asked. "Take some water out?" asked James. James went back to the bathroom and tipped some of the water out *(Figure 8.)*. I suggested that we wait for it to dry first before fixing the boat and try again later in the afternoon.

At 2:00pm, James took off the old sticky tape and re-stuck the pieces of the boat together. This time, instead of putting the containers next to each other on the long side, he put them together on the short side *(Figure 9.)*. He picked up Sally and the bottle and said, "This one's heavier," referring to the bottle *(Figure 10.)*. "What do we need to do?" I asked. "Tip some out," said James. We then went outside to test the boat. It floated on the water with Sally inside, her head towards the middle for a short period of time *(Figure 11.),* but then it sunk.

Figure 1.

Figure 2.

Figure 3.

Figure 4.

Figure 5.

Figure 6.

Figure 7.

Figure 8.

Figure 9.

Figure 10.

Figure 11.

Analysis (I Think):
James had multiple ideas including, adding layers to the boat, putting "cushions"" in the boat, putting an object in to distribute the weight and attaching the two containers by the short side instead of the long side. Through inquiry questioning, he reflected critically on his idea of taking the bottle off after it had sunk, realising that the boat would be too heavy on one side with Sally in it and generating a solution to make the bottle lighter by tipping out water. By using water in a water bottle as a weight, James used an object in a way other than its intended use. The initial

design was modified and James demonstrated a purpose for his actions, tried out new arrangements, problem solved and showed delayed gratification, continuing to modify his boat until it was finally able to float on the water with Sally inside. The boat was original, effective and for for purpose. Adam did not contribute as much to this activity but still had a purpose for his actions, helping to put together the boat and filling up the water bottle to use as a weight. He shared his idea of making it a cruise ship and made a suggestion to add more sticky tape when the boat collapsed in the middle.

Where to next (I Wonder):
We will revise what happened next week and make another attempt to make the boat float with Sally inside. I Wonder if Adam and James will still show resilience or if they will give up after having so many attempts.

LS 2.6

Learning Story

Child's Name: Adam and James	Cycle Two
Date: 12th December 2019 (Length of time: 14mins)	Author/s Name: Chloe

Story (I See):
"James and Adam, remember you did your boat last week, and what happened to it?" I asked. "It float and then it sank again," said James. "So what do you think we need to do this time? How can we change it so that it will float?" I asked. "Put this in the middle?" asked James about the Styrofoam. "Do you think that would work?" I asked. "No" replied James. "Because we have to put Sally over here don't we?" I said pointing to the container. "Yeah, then it will tip over like" said James tipping the container over. "Who was too heavy? Was it the bottle or Sally that was too heavy?" I asked. "Sally, Sally," said Adam "Umm… The bottle!" said James. "No, Sally," said Adam. "No one time we tested it without you," said James. "Oh, because Adam was sleeping wasn't he?" I said. James told Adam what happened about it floating first but then sinking again. "What do you think we could do to make the bottle lighter?" I asked. "Pour a tiny, tiny bit more down the drain," replied James. James tried to detach the bottle but I told him to leave it on so he doesn't have to break it and suggested taking the lid off and then pouring it into the sink. James went to pour some water down the sink. Afterwards, I asked the children, "How are you going to attach this part of the boat to this part?" pointing to each container. James started pulling sticky tape. "Are you going to use some sticky tape?" I asked. "How about electric glue?" asked Adam. "Electric glue?" said James. "Chloe, there's actually electric glue," Adam said. "Do you mean the glue gun?" I asked. "Yes. How about the electric glue, is there such thing as electric glue?" said Adam. "I don't know, I haven't heard of electric glue I've heard of a glue gun that uses electricity," I said. "And one time I got burnt by it," said Adam. Jasper continued to use sticky tape to attach the containers together. I suggested taking Sally out so it would be easier to tape together. "Do you need a long piece or a short piece?" I asked. "Long piece," said James. I then asked, "Does it stick together?" James said, "Yes." So I asked him, "Do you think if we put it in the water it will float? What happens if we lift it up?" I asked. James lifts it up. "Does it stick together?" I asked. "Nah," said James. "So what do you need to do now?" I ask. "Get another long piece and put it across," suggested James. "Do you think that's going to help it stick together though?" I ask. "I Think," said James. Adam puts small pieces of sticky tape to reinforce the side. "How do we even do this, it's kind of wobbly." Said Adam. "Do you think you should put sticky tape on the top or the bottom?" I ask. "On the top," replies James. "Chloe, how is sticky tape made? What is sticky tape made out of?" asks Adam. "Plastic," replied James. "What's the sticky part?" asks Adam. "The sticky part is glue," says James. The children finished sticky taping the containers together. James suggests sticky taping the lid to the bottle but I suggested leaving it as it is in case they need to take some more water out of the bottle. We then went outside to test it. The boat sunk again. "What happened that time?" I asked. "It sunk," said James. "So what do we need to do so that it will float?" I asked. "Umm.. put some extra weight on it?" replied James. "Put extra weight on it do you think or do you think less weight?" I asked. "Extra weight," replied James. "What will happen if we put more weight on there?" I ask. "It will… fall over again," said James. Next we put the boat

back together using sticky tape. “Was it sinking from this side here (pointing to left) or this side (pointing to right) or from the middle?” I ask. “The middle,” said James. The children continue to put the boat back together. James decided he needed to put extra sticky tape on the top and the bottom to stop the boat from coming apart in the water. Adam helped him. Once they were finished sticky taping I asked, “Now where do we need to put the bottle?” James replied, “In the middle!” I then said, “Do you think in the middle? Because remember it was sinking from the middle.” James then said, “No,” and pointed to the left side. James and Adam then sticky taped the bottle onto the left side of the boat. We then went outside to test the boat in the water trough. The boat managed to float on the water with Sally inside. We then went inside and discussed what happened. “What happened that time when we tested the boat?” I asked. “It sank,” said Adam. “Did it?” I asked. “No” said James. “It floated,” Adam then said correcting himself. “Was it the same as the original drawings we did?” I asked. “No,” said James. “How did we make it different, what did we change?” I asked. “It was, but this part was like this,” said Adam pointing to one rectangle of the boat. “Yep, that’s right so the rectangle piece, there was one rectangle piece that was like that, that was yours Adam. But when we did the one rectangle piece did it float or did it sink?” I asked. “Sink,” both children said at the same time. “So then what did we do?” I asked. “And then we just, we did,” said Adam and pointed to the other piece of the boat. “We did another one, we got another piece and stuck it together.” I helped Adam reply. “And then what happened when we put Sally in the boat and tested it out?” I asked. “It sunk,” said the boys together. “So then James came up with an idea, that we could put?” I asked. “Water in a bottle,” said James. “To make it float, and when we tested it out what happened?” I asked. “It sunk,” said James. “It sunk again, but why do you think it sunk?” I asked. “Because the bottle was too heavy,” said James. “So, what did we do?” I asked. “And then we tipped some out and then we,” said James. “And then we put it in the water trough and it floated,” said Adam. “Yeah but how come it floated the last time? We tipped some water out today and then we tested it again but it sunk and it fell which side did it fall from? The left side, the right side or the middle?” I asked. “The middle,” said James. “So, what did we need to do?’ I asked. “We needed to put it there,” said James pointing to the left side. “You needed to move the bottle onto the left side,” I replied. “So, why didn’t the first work?” I asked. “Because the bottle was full,” said James. “Because it was too?” I asked. “Heavy,” said James. “And it was in the wrong?” I asked. “Place,” said Adam. “So we had to even it out didn’t we? Put Sally on one side and the bottle on the other side, so it would go?” I asked. “Flat,” replied James.

Analysis (I Think):
James had a few ideas on how to make the boat float this time. He first suggested putting the water bottle in the middle but after some prompting he realised it would tip the boat over once Sally was in the boat. His next suggestion after asking which was heavier, Sally or the bottle and how the bottle could be made lighter, was to tip some more water out of the bottle, generating a solution to solve his problem of the boat sinking.
Adam asked a few questions in this session. He asked about using “electric glue,” How sticky tape is made and what it’s made out of. The tone which James replied, “Electric glue?” to Adam implied that he could have thought he was joking or that there is no such thing as electric glue but I interpreted it to mean the glue gun. Adam said afterwards, “Chloe, there’s actually electric glue,” challenging James’ assumption towards his idea of using “electric glue.”

Both James and Adam continued to have a purpose for their actions and use objects in a way other than their intended use. They were both open to and tried out new arrangements with their new design, modifying their initial designs.
James generated a solution to solve the problem of the boat sinking, he put the bottle on the left side and put Sally on the right as well as tipping out some water from the bottle that was used as a weight.
Both the children reflected during the creating process answering questions such as, "Was it the bottle or Sally that was too heavy?" But only James reflected on the process for solving the problem/constructing the product including, "What do you think we could do to make the bottle lighter?" and "So what do we need to do so that it will float?"
At the end of the session after the boat was successful both children were able to answer the reflective questions, evaluating the product for its effectiveness and being fit for purpose. They demonstrated resilience and self-determination after having so many sessions to finally be successful and create a boat that floats. Also they collaborated well with each other, James playing more of a leading role than Adam.

Where to next (I Wonder):
I Wonder if I didn't tell James to take the lid off the bottle when he wanted to detach the bottle to tip out some water and prompt him more by still stopping him and telling him he could leave the bottle on but then asking how he could do it without breaking his boat, if he would have figured it out by himself. I Wonder how James and Adam will collaborate with another peer in Cycle three, and if James will still play a lead role.

LS 2.7

Learning Story

Child's Name: William	Cycle Two
Date: 3rd December 2019 (Time: 11:00am to 11:30am)	Author/s Name: Chloe

Story (I See):

I introduced Sally the doll to William and told him her problem, that she needs to get over the river. I asked William, what we could make for Sally that will help her get across the river. He suggested a bridge. I then asked him what else we could make. "A boat, "William said. I showed William some pictures of boats and he pointed out the types of boats he had seen before. I asked him the difference between a sailing boat and one of the boats with an engine. "It doesn't have that" William said pointing at the sails. I asked him if he knew what they were called, he didn't so I told him they were called sails. William said one of the boats looked like it had shoes. I asked him what he thought they were for. "To keep it floating," he said. I then said to William that we will be designing a boat to get Sally across the river. I told him to have a look at the different materials I had so he could get an idea of how he might like to make his boat. I asked him if we could use cardboard and if it would work in the water. He said it would float in the water so we went outside and tested the egg carton by putting it in the water trough *(Figure 1.)*. After testing it, we went inside and I asked William what happened to the egg carton after putting it in the water. "It gets all soft," he said. "So do you think we could use cardboard?" I asked. "Mmmm," William said shaking his head as if to say no. I asked William if he thought the plastic containers would go soft in the water. "Mmhmm," William said at first. I suggested we go test it out. He then said "It won't, I know it won't." I asked him if he still wanted to test it out and he said yes. We went and tested it out and when we came back I asked William how the plastic container went in the trough. "It stayed hard," he said. "Did it float?" I asked. "Yeah," said William. I then asked William if he could draw what he thought his boat would look like. "What shape would your boat be William?" I asked. "I Think a rectangle," he said. William then drew a rectangle. He then drew another and included Sally laying in the boat in his design *(Figure 2.)*. He put Sally into the container and I asked if he thought Sally would float in it. He said yes, so we went outside to test it out in the water trough. Sally tipped over so we went inside and discussed what happened *(Figure 3.)*. "What happened to Sally when we put her in the water?" I asked. "She fell," he said. "Why do you think she fell?" I asked. "Because she's heavy," said William. "What do you think we need to do to our boat so Sally will float?" I asked. "Put two together," said William. William put two containers together and put Sally in one of the containers *(Figure 4.)*. William chose two new containers that weren't wet. He attached them together using tape. "Do you think two containers will be enough," I ask. "Mhmm," replies William. William finishes attaching his two containers together so we went outside to test again. When William put his boat into the water, it broke. He still wanted to test if it would work in the bigger container. William put Sally on the left side of the boat and she tipped to the left *(Figure 5.)*. I then asked William if Sally could go somewhere else on the boat. He put her on the right side and she tipped to the right side *(Figure 6.)*. I then asked William what would happen if Sally would go in the middle. He tested it out and she managed to float *(Figure 7.)*. When we came back inside we revisited what happened. "What happened to the second boat we made?" I asked. "It sunk and float," said William. "What happened when we put Sally on the very left side of the boat?" I asked. "Umm it sunk," he said. "And then what happened when we put Sally on the very right side of the boat?" I asked. "It sunk." William replied. "But what happened when we put Sally in the very middle of the boat?" "It didn't sink!" said William. "Did you make your boat the same as your initial design?" I asked William. "No," he said. "How is it different?" I asked. "Because it wasn't a square…. Rectangle," he said. "When you made your rectangle, you put another container on the end, didn't you? What happened to that container?" I asked "It broke," said William. "But did we need to have the other container on there?" I asked. "No, because it can go on its own," said William. "It could float by itself," I said. Asked William, "Why do you think the first design didn't work?" "Cause Sally was heavy," said William. "And why do you think the second design worked?" I asked. "Because we put her in the middle," said William. "Did we put her in the middle of this one too?" I asked referring to the first boat William made. "Yes," said William. "Why do you think the second design worked then?" I asked. "Cause we put her in the middle," he said. "We put her in the middle of this one too, what made it different to the other boat? What made it different? Was it the same shape or a different shape?" I asked. "It was a different shape," said William. "What shape was this one?" I asked. "Rectangle," said William. "They were both rectangles, weren't they? Was there a difference with the size?" I asked. "That one was bigger and that one was smaller," said William. "So what did we need to do to make Sally float? It needed to be?" I asked. "Big!" said Archie.

Analysis (I Think):
William had two ideas, to make a bridge for Sally to get across and to make a boat. Sally tipped over in William's first boat. He proposed a possible solution, that if he put two containers together Sally would float, drawing together two objects to make something new. By using the plastic containers, William is using the objects in a way other than its intended use. William modified his initial design from 1 container to 2, but then went back to 1 container but of a different size. William tried out new arrangements of where Sally could sit in the boat. He tried the left side, the right side and then the middle where she was able to float, also generating a solution to solve his problem of Sally sinking. William had a purpose for his actions, to build a boat for Sally the doll to float. William shows resilience as he tests out his ideas/creations several times. Through the Inquiry Questioning Model, William was able to reflect critically during the creating process. He thought about why his boat sank and how he could make it float. William's product was effective and fit for purpose however, it was not original being a plain container. Also through the use of the Inquiry Questioning Model, William was able to reflect critically and evaluate his end product, how he managed to make his boat float with Sally.

Where to next (I Wonder):
William suggested to make a bridge, I Wonder if he could make a bridge in the next cycle? I Wonder if William will show more originality in the next product he makes in Cycle three. Will he show the same or more indicators of creativity in cycle 4, or does the prompting questions from the framework allow for more creativity?

Figure 1. *Figure 2.* *Figure 3.*

Figure 4. *Figure 5.* *Figure 6.*

Figure 7.

LS 2.8

Learning Story

Child's Name: Olivia	Cycle Two
Date: 11th December 2019 (Time: 10:15am – 11:00am)	Author/s Name: Chloe

Story (I See):

I introduced Sally the doll to Olivia and told her she needs to get across the river, our trough outside. I asked Olivia, "What can we make for Sally to get her across the river?" "A boat," said Olivia. I showed Olivia pictures of different types of boats. "Are they the same types of boats or are they different?" I asked her. "Different," she replied. "How are they different?" I asked. "Because some have sails, some haven't," said Olivia. I asked Olivia what was underneath one of the inflatable boats and what its purpose was. "So it can float," said Olivia. "You have to put air in it," she added. I asked her how some other boats move. "With these," she said about the oars on the rowing boat. I then asked her about a sailing boat, "with sails, we put the sails up and the wind blows it along. So they don't have to do anything," Olivia replied. When I asked about the speed boat, Olivia said that it moved using the engine. We looked at the different materials I had collected and I asked Olivia, "Do you think we could make it out of cardboard?" "No, because then it might get too soggy and then it might sink," she said. "What could we make a boat out of?" I asked. "Plastic," said Olivia. "And then you can put water in these and then you can put it on things so it floats very good," said Olivia referring to the juice bottle. "Maybe the string will be good to tie all of it together," said Olivia. "We could also use some sticky tape or some glue," I replied. "Yeah sticky tape will be I Think a bit better. Because then this might get a bit dirty and soggy then it might not be so good. Might not hold very good," said Olivia. "So which kind of containers do you think you could use?" I asked. "I Think we could use for a big boat, we could use something like this to have two things in it like that *(Figure 1.)* and maybe for a little boat we could use these *(Figure 2.)* but I would be better to use one of these to make a medium sized boat because I would like to make a medium sized boat *(Figure 3.)*," said Olivia. "Remember, who the boat is for. Who's the boat for?" I asked. "Sally," replied Olivia. "This might be a bit better because it's longer but if we didn't have this on it might sink with no water in so we might have to fill this up so it can float.," said Olivia referring to the container with two sections and the juice bottle *(Figure 4.).* I asked Olivia why she would have to fill it up. She said, "so it doesn't sink under the water," and the proceeded to tell a story about seeing two boats sink and that it will be "too heavy, because one side might be a bit too heavy, one side too light and then that side will go down and that one will stay up and then it will sink." I asked Olivia if she had seen someone do that before. She said no. I then asked Olivia to draw her boat *(Figure 5.)*. Her design included the two containers, Sally and a sail. I then asked Olivia what she would use to make the sails. She decided to use a Slurpee straw as the pole and paper on top to make the sail. "And then it might sink but I Think it won't with sails because sails are pretty light but still with the bottle on the other side will make it more better so I Think now I can put some water in," said Olivia. We couldn't find the lid for the bottle but had a variety of lids in the art trolley. Olivia tested to see which ones would fit. She found one that fit but it wouldn't screw on. "What else could we do so it stays on?" I asked. "We could tie it on… Maybe we could sticky tape it on," replied Olivia. "Do you think we need a lot of water, or do we need a little bit of water?" I asked. "Um maybe medium amount for Sally because Sally is pretty heavy," said Olivia. "Can you feel how heavy Sally is?" I asked. Olivia held up Sally in one hand *(Figure 6.)*. "Yeah, I Think she's pretty heavy. With one hand she's pretty heavy but with two hands it's middle so I Think we'll put a medium amount," said Olivia. We then went to the bathroom to fill up the bottle. "Do you think that's a good weight?" I asked Olivia. Olivia picked up Sally in one hand and the bottle in the other, hefting to check the weight *(Figure 7.)*. "Sally feels lighter now," she said. "So, what do you need to do?" I asked. "Tip a little bit out," said Olivia. Olivia went to the bathroom and tipped some of the water out of the bottle *(Figure 8.)*. We brought Sally into the bathroom to test and see if there was enough water emptied out of the bottle *(Figure 9.)*. Olivia wrapped tape around the lid so the water wouldn't leak out. "Should we put that on the boat? How will you attach that onto the boat?" I asked. "With sticky tape," replied Olivia. She placed the bottle inside the container. "Now does Sally still fit on the boat with that there?" I asked. "No," said Olivia. "How can we make it so that Sally will fit as well?" I asked. Olivia placed the bottle on The edge of the container so there would be enough room for Sally to also fit *(Figure 10.)*. She began sticky taping the bottle to the container. "That feels good," she said, making sure the bottle was attached to the container. "Do you think Sally would stay there or do you think you need to put her in a different position?" I asked. "What?" asked Olivia. "Do you think on her back would be the best way to put her?" I asked. "No," said "Which way?" I asked. "On the side would be a bit better," said Olivia. "What are you going to make the sail out of?" I asked. "Paper," said Olivia. She went and got some coloured paper off the art trolley. Olivia folded the paper into a triangle and cut off the end to make her sail *(Figure 11.)*. She then attached the triangle piece onto the Slurpee straw using sticky tape. When trying to attach the straw to the container, the sail wouldn't stay upright. "How else could you stick it?" I asked. "With the masking tape," replied Olivia. "Do you think that will make it stand up?" I asked. "I don't know," said Olivia. "Where else could you stick it? Does it have to be on the top? Or could you stick it somewhere else?" I asked. "I could stick it somewhere else maybe there," said Olivia pointing at the side of the container. She proceeded to stick it on using the masking tape *(Figure 12.)*. Olivia finished creating her boat. We went outside to test it out in the water trough. The boat initially floated on top of the water but slowly it begun to sink and water filled up inside the boat. We went inside to discuss what happened. "What do you think would make your boat float? What could make it better?" I asked Olivia. "Maybe put a bit more water in or a bit less," said Olivia. "What do you think? More or less water? Because it made it sink, didn't it?" I said. "Less," said Olivia. "It was too heavy wasn't it, so we need to take out some water don't we?" I said. Olivia took off the sticky tape around the lid and tipped out some water. Olivia put the lid on, sticky tapping it back onto the bottle. We then went outside to test the boat again. Olivia decided to tip all the water out of the bottle but this caused the boat to sink as Sally was too heavy. She then put a small amount of water inside and the boat managed to stay floating on top of the water *(Figure 13.).* We then went inside to debrief what had happened. We went over what happened the first time. "It sank," said Olivia. "So then what did we do?" I asked. "We tipped all of the water out," said Olivia. "And then what happened after that?" I asked. "It tipped over like that," said Olivia. "Tipped over the other side, Sally was too heavy wasn't she? So then what did we do?" I asked. "We just put little bit of water, and then it floated!" said Olivia excitedly. "Was it the same as your initial drawing?" I asked. "Yeah," said Olivia. "What did you do to make it work?" I asked. "Just put a little bit of water," replied Olivia. "So why didn't the first one work?" I asked. "Because there was too much water. Then we put a little bit less in, pour all of it out and then it was too less, then we put just a little bit and it was just right!" said Olivia.

Analysis (I Think):

Olivia had multiple ideas. She had ideas of how she could make a small boat, a big boat and a medium sized boat. She made a connection between things that are not usually connected, such as using a juice bottle with water inside as a weight as well as a Slurpee straw and paper for a sail, imagining multiple uses for these objects and using them in ways other than their intended use. Olivia maintained her design, adjusting the water level in the bottle until the boat would float. Olivia came across a problem when there was no lid for the juice container she would fill with water. She found a lid that would fit from the art trolley but it wouldn't screw on tight. At first she thought of tying it on but then changed her mind and said she could sticky tape it on, generating a solution for her problem. Olivia demonstrated that she had a purpose for her actions and reflected during the creating process, thinking about whether she needed to add or take water from the bottle and how she could attach the sail without it falling down. She showed resilience when her boat would sink, and she would take water out of the bottle or add more, also showing self-determination. Olivia's boat was effective and fit for purpose as it ended up floating on the water, but it was very similar in design to the boat Adam and James made. She reflected upon and evaluated her end product during the reflecting and reasoning stage after testing out her boat, responding to the questions I asked, relaying what had happened.

Figure 1.

Figure 2.

Figure 3.

Figure 4.

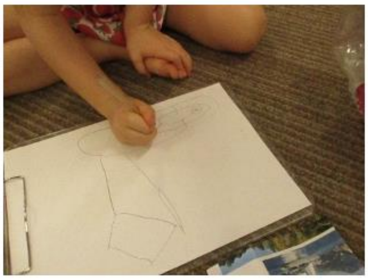


Figure 5.

Figure 6.

Figure 7.

Figure 8.

Figure 9.

Figure 10.

Figure 11.

Figure 12.

Figure 13.

Where to next (I Wonder):

Olivia's idea of filling up the juice bottle was the same as Adam and James', I Wonder if she saw them making their boat and knew that if she were to do the same that her boat will also float? I Wonder if she didn't use the bottle, would she have made a boat that would be able to carry Sally's weight? As Olivia's boat was a success, we will move onto Cycle three, making a bridge for the Billy Goats Gruff to cross over.

LS 3.1

Learning Story

Child's Name: Sarah and William	Cycle Three
Date: 10th December 2019 (Time: 10:55am – 11:30am)	Author/s Name: Chloe

Story (I See):

I introduced the lesson to the Sarah and William, asking them what they thought they would be making. Sarah thought they would be making more boats but William saw the figurine goats and said, "3 Little Goats." I then asked if they could remember what happens in the story of the Three Billy Goats Gruff. William said, "The troll falls into the water." I then asked, "And what did the Three Billy Goats Gruff want to do?" "Cross the Bridge," said William and Sarah together. "Now, we've got the river here, and we've also got the green grass that the Billy goats want to get to so that they've got nice yummy grass to eat, but what are we missing?" I asked. "The bridge," said William. "How could we make the bridge?" I asked. "We could first stick a stick then cut a straw in half and put one on each side," suggested Sarah. "Let's have a look at some pictures of bridges," I said, then showed the children photos of different types of bridges. "Have a little look at some of these bridges, and have a think about how you can make your bridge, what shape it will be?" Sarah and William then drew their designs *(Figure 1.)*. "To get over the water here, does it need to be very long or does it need to be shorter?" I asked. "No, needs to be that short," said William referring to the width of the water. "So are you going to make a straight bridge or will your bridge have curves?" I asked. "I want mine to be straight," said Sarah. "I want mine to be straight too," said William. "Sarah, I know you've done where they will walk, but how will the bridge stand, because are bridges flat on the water or is there a bit of a space?" I asked. "A bit of a space," both Sarah and William replied. "So what do you need to put underneath?" I asked. "Water" replied, Sarah. "And then how will your bridge here, stand?" I asked pointing to the ends. "It's going to stand in the water," said Sarah. "And how is yours going to stand, William?" I asked. "I put it in water and I did a little fishie," said William. "But where are the legs that can stand?" asked Sarah. "How is your bridge going to stay up, William?" I asked. "Legs," said William. "Now what are you going to use, Sarah? Are you going to use some popsticks, or are you going to use straws?" I asked. "I'm going to use straws and popsticks," said William. "I need two popsticks, one and two, these are all I need," said Sarah. She then decided to use the cups as the "legs" of the bridge. I said to Sarah and William, "Now, have a look at your design, you've got some legs, do you have a flat piece that's going go where the Billy Goats Gruff will walk?" "Oh yeah these," said Sarah referring to the popsticks. "How are you going to make it big enough for the Billy Goats Gruff?" I asked. "I can use lots of them," said Sarah. "I'm going to draw some paddles," said William. I asked him, "What are the paddles for?" "To make the bridge go. 'Cause I've seen some bridge move before," said William. "Yeah, some bridges do move," I said. "No they don't," said Sarah. "There are some bridges that come up and go down," I said, levering my hand like a bridge going up and down. William replied, "Yeah that's what I'm doing, up, down," said William in the same way I said up and down. "Ok, now I need two cups, I need two of these," said Sarah referring to the two plastic cups and two round plastic containers. "What are you using those two for?" I asked. "So this is going to be here, and that's going to be here then these are going to go with the lids, that's how

I'm going to do it," said Sarah placing the round plastic containers (lids) over the top of the plastic cups *(Figure 2.)*. "Do you think your lids will be strong enough to hold all three billy goats gruff?" I asked. "Mhmm," said Sarah. "And how wide does your bridge need to be to get over the water?" I then asked. "This wide," replied William, pointing to the width of the river. "What about we make it together so it be the biggest bridge!?" Sarah asked excitedly. "You want to make it together?" I asked looking at William. William nodded. "Yeah? Which design are you going to go with?" I asked. "You both have very similar ones though, didn't you?" I said. "Yeah," said William. "You have legs, you had flat and you had bits at the top as well. Are you still going to have bits coming at the top?" I asked. "Oh yes," said William. "So where are your legs going to go? Can you place your legs by the river?" I asked. "Wait, I need two of these," said William referring to the plastic cups. He then placed one cup on the ground upside down, then another cup on top the other way around and then a round plastic container on the top which elevated the top container *(Figure 3.)*. "Now look at mine," he said. "Oh that's a good idea, William," I said. "What did William do anyway?" asked Sarah. "Put two cups," said William. Using the masking tape, Sarah made one leg of the bridge using William's design *(Figure 4.)*, and William made the other *(Figure 5.)*. "Where would you place those legs? Would you place them on the shoreline or on the river?" I asked. "On the river," said William. "I want to place one on here and on here," said Sarah, putting the cups on the shoreline. "Ok, I'm going to do that too," said William. "Look what I'm doing," said Sarah. "That's a good idea," said William "Look at me go around and around and around, I need some more tape," said Sarah putting the sticky tape from the edge of the round container to the middle of the plastic cup *(Figure 6.)*. "I'm like making a star," said Sarah. "It does look a bit like a star," I said. "I'm going to make like a star so it's night time and the bridge is like lighting up a star," said Sarah. "And add some batteries and it can light up so we can put some lights in it," said Sarah. "But don't put it in the water or in the bath, I put my boat from school in it and it broke so don't do that," said William. "Why? It's not paper, paper can only break not these," said Sarah. "We made it out of playdough, playdough can break" said William. "Will we still make one together or are you going to make them separate?" I asked. "Make them together," said William. "Sarah and William, do you need to make the legs the same height?" I asked, as Sarah had one plastic cup under the round container and William had two. They discussed what they could do to make their bridge work. "Remember your initial designs as well, your pictures that you made, so remember it needs to have a straight top," I asked. "What if the 3 billy goats sink in?" asked Sarah. I replied, "We don't want them to sink in do we, so we need to make it very," "Strong!" said William. "I need a lot of these, to make it look interesting," Sarah said about the straws. "What would happen if we attach lots and lots of these together," I said about the straws. "What if we attach all of them together?" asked Sarah. "Do you think that would be strong enough for the billy goats to walk over?" I asked. "Yeah, that would," said Sarah. "What are you going to make as the flat part?" I asked. "There, like that," said Sarah putting all the straws together. "How can we stick them together?" I asked. "With tape," said Sarah. Sarah used the tape to stick the straws together *(Figure 7.)*. "There, that much," said Sarah measuring the sticky tape over the width of the bundle of straws *(Figure 8.)*. "Do you need anymore sticky tape? Is it sturdy enough, strong enough to hold the billy goats?" I asked. "Nah," said William. "Do you think it needs more sticky tape?" I asked. "It can go like this," said William putting it on the leg. "But how are they going to climb up? But what happens if they go on too high?" asked William. "Do you think these legs are too high?" I asked. "Yeah," said William. "Do you think we could make the legs a different way?" I asked.

"Yeah," replied William. I then asked, "What could we use instead of these legs?" "Mmm, like that," said William taking off the bottom plastic cup. "We can take the bridge home? Or one of us?" asked Sarah. "Because you're sharing it, maybe we can leave it here or if you make one each then you can take it home," I suggested. "Ok, I Think this will be mine and then we'll help William make his because I made this," said Sarah referring to the legs she made and the flat top of the bridge. "I want to try all together," said Sarah placing the straws on top of the legs and the 3 Billy Goats Gruff on top. "Does it hold?" I ask. "Yay!" said Sarah celebrating. "Yeah it does, it's strong enough isn't it?" I said *(Figure 9)*. She used the sticky tape to attach the top, flat part of the bridge to the legs. Meanwhile, William was making his own bridge. He gathered a bunch of straws and stuck them together in the same way that Sarah did. "All done," he said *(Figure 10)*. "And then we make another one," said William making another leg for his bridge. Sarah finished off attaching the top, flat part of the bridge to the legs and tested it out again making sure that the bridge could hold the 3 Billy Goats Gruff *(Figure 11.)*. I then said to Sarah, "Your one worked didn't it Sarah? Did you need to change anything?" "No," replied Sarah. "We did need to change something," said William. "What did you need to change?" I asked William. "The cups," replied William. "The cups that's what you did change wasn't it, so it was a bit different from your first drawing wasn't it Sarah?" I said. "Yeah," said Sarah. "How is it different?" I asked. "The long stem," said Sarah. "The legs? How did you make the legs instead" I asked. "I just put these on," "You just used the big cups," I said. "And what else is different from the original design? Remember you had these going up?" I asked. "Do you think you needed to have these going up to make it strong enough for the billy goats?" I asked. "I don't think," said Sarah. William finished creating his bridge and tested it out with the 3 Billy Goats Gruff. "Yes!" he said celebrating the bridge holding the weight of the billy goats.

Analysis (I Think):
Sarah asked William a question, "But where are the legs that can stand?"
William said that some bridges move, Sarah disagreed. I thought William was referring to drawbridges, but he could have also meant bridges like what we have in our playground with rope and wood that can move. William challenged Sarah's assumption about bridges not being able to move.
Both Sarah and William used objects in ways other than their intended use. They used straws, plastic containers and cups to make a bridge. They were also both self-determined and stayed with the task until it was completed.
William came across a problem that he reflected on during the creating process. He said that the bridge would be too high for the Billy Goats Gruff to climb onto. He generated a solution to solve his problem and tried out a new arrangement, by taking off the bottom cup which made the legs of the bridge shorter. This changed his initial design. Sarah also modified her initial design, removing the spikes that went along the sides of the bridge.
Both Sarah and William had a purpose for their actions, each creating a bridge for the three billy goats gruff to cross. Their bridges were original, effective and fit for purpose. They reflected and evaluated their products.

Where to next (I Wonder):

This activity only took one session to achieve. I Wonder if it is because the children have been through the design process already or is it because this activity was easier than creating a boat that floats?

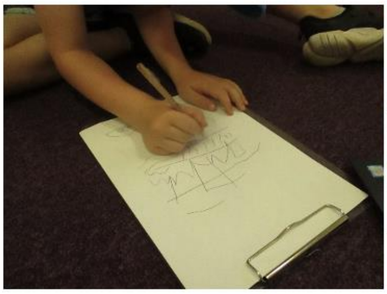


Figure 1.

Figure 2.

Figure 3.

Figure 4.

Figure 5.

Figure 6.

Figure 7.

Figure 8.

Figure 9.

Figure 10.

Figure 11.

LS 3.2

Learning Story

Child's Name: James, Adam and Olivia Date: 12th December 2020 (Time: 4:00pm – 4:25pm)	Cycle Three Author/s Name: Chloe

Story (I See):

I set up the activity with some blue paper as the water, artificial lawn piece as the grass, the 3 Billy Goats Gruff figurines and different materials the children could use to make a bridge. I asked the children how we could get the Three Billy Goats Gruff over the river. "A bridge," said Olivia. I showed the children some photos of different bridges. "Where's Sydney Harbour?" asked James. I didn't have a photo of Sydney Harbour but Adam said his dad has been there. "What shapes are bridges? Are they straight? Are they curved?" I asked. "These can be the reports for the bridge," said James. "The supports?" I asked. "Yeah," said James referring to plastic containers. We decided to make one bridge all together. I showed the children the different resources/materials they had to use and asked them to draw their design before making the bridge. "I know, these can be the stands," said Adam referring to the plastic cups. "How would you draw that? How many stands do you need?" I asked. "I Think 4," said James. "Do you think 4 Olivia?" I asked. "I Think, 10," said Adam. "Where would you put the stands?" I asked. "On the side," said James. "Here, here, here, here," said Olivia pointing to two spots on one side of the river and two spots on the other side of the river. "Where do you think we'd put those cups to make them stand?" I asked. "Or maybe like that," said Olivia turning one upside down. "How wide do we have to make it?" I asked. "Very wide," said Adam. Olivia pointed from one side of the water to the other. "It has to be as wide as the river, doesn't it?" I asked. "Should we measure the river? What could we measure the width of the river with?" I then asked. "Measuring tape?" suggested James. "Or a ruler," said Adam. "What's something that we've got here that we could use instead?" I asked. "Straws," said James. "How many straws will cross the river?" I asked. "One," said James. "Is the straw bigger than the river or is it smaller than the river?" I asked. "Bigger," the group said. "What's something that's smaller for measuring?" I asked. "We could cut the straw in half?" suggested James. "No, we have to do it here," said Olivia pointing to the end of the straw that went past the river *(Figure 1.).* Olivia cut the straw so it was the same width of the river. "What are we going to make the top of the bridge from?" I asked. "These," said Olivia picking up a popstick. The children then drew their designs. We talked about what view of the bridge the children will draw. James drew the bridge side on. "Where will you put your support or stand?" I asked him. "On the back," he replied. I showed him one of the pictures of a bridge, "See here, where are the supports on these pictures?" "Here," said James pointing to the stands at the bottom of the picture. "On the bottom, maybe you can draw your supports down the bottom? What does it look like from the side? Does it look like a circle shape or does it look like a different shape?" I said. "A different shape, it looks like a cylinder," said James *(Figure 2.)*. "Chloe, drawn the circles, two, two, two, two" said Adam. Adam used the cup as a stencil to draw the supports of the bridge. "Where are you going to put the top of your bridge?" I asked Adam. Adam drew up from the circle, across and down *(Figure 3.).* Olivia also used the cup as a stencil but drew two circles and the popsticks on top to represent the walkway of the bridge *(Figure 4.).* “So, if we’re using these, how are we going to stick them together?” I asked holding up the popsticks. “With sticky tape,” said Olivia. “How do they go together?” I asked. “I Think we could do it like that,” said Olivia placing the popsicks next to each other on the long side. The children then started placing the popsticks side by side *(Figure 5.).* “I have an idea Chloe, we could get a piece of paper, we could stick it on the cups with sticky tape,” said Adam. “Do you think that would hold the Three Billy Goats Gruff? Do you think that would be strong enough?” I asked. “No, it will rip,” said James. “But these will be strong enough,” said Olivia referring to the popsticks. The children put the straw, that they had used to measure the water, underneath the popstick walkway they were making to ensure that the bridge would be long enough *(Figure 6.).* “What sticky tape would you like to use for sticking? Do you think we could use the clear one or the masking tape?” I asked. “Masking tape!” exclaimed James. “Is masking tape strong Chloe? Stronger than the light tape?” questioned Adam. “What do you think?” I asked. “Stronger,” said all three children. “Let’s see if its strong enough to hold all these popsticks,” I asked. James cut some masking tape and placed it on the popsticks. Adam pulled some masking tape and I asked, “Do you think that’s too long or…” “Too long,” said Adam. He then cut the masking tape so it was the same length as the popsticks. “Ooh that’s way too long,” said James. “That’s ok, what could we do?” I asked. “Turn it the other way, Adam,” said James *(Figure 7.).* Olivia put one more piece of tape on to make sure it was strong enough *(Figure 8.).* The children then put the top of the bridge on the 4 plastic cups *(Figure 9.).* “Now, how are we going to attach it so it doesn’t slip?” I asked. “Masking tape, because masking tape’s the strongest,” said James *(Figure 10.).* “Then we’ll test it out,” I said. The children took turns in getting masking tape and attaching it to the walkway and the supports. When they finished they put the Three Billy Goats Gruff on top and the bridge held their weight. “Did it work?” I asked. “Yeah!” said Adam and Olivia. “Is your bridge sturdy enough to hold the Three Billy Goats Gruff?” I asked. “Yes!” said the children. “Did you need to change anything?” I asked. “No,” said James. “Is it the same as your drawings?” I asked. “Yeah,” said Olivia.

Figure 1.

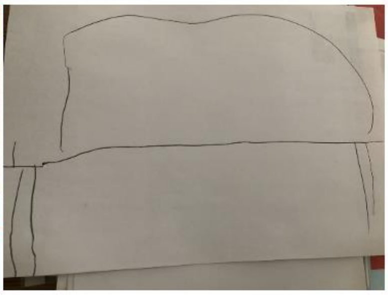


Figure 2.

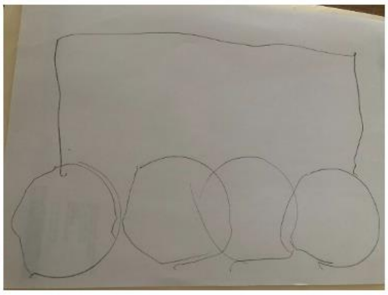


Figure 3.

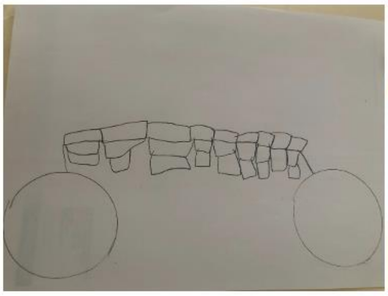


Figure 4.

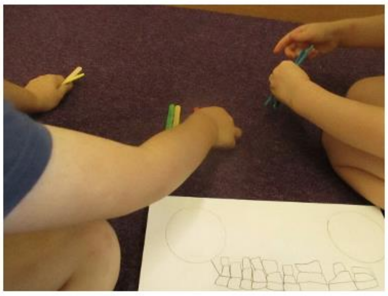


Figure 5.

Figure 6.

Figure 7.

Figure 8.

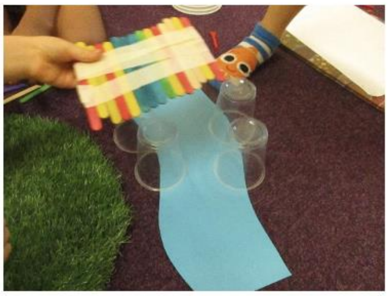


Figure 9.

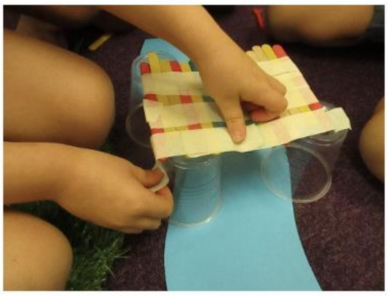


Figure 10.

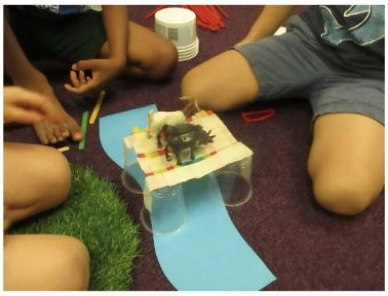


Figure 11.

Analysis (I Think):

James came up with the idea of using a straw as something to measure with, using the straw in a way other than its intended use. The children used the popsticks and plastic cups to make their bridge, using them in a way other than their intended uses.

Adam had an idea of using paper as the walkway of the bridge. This may have worked and we could have tested it if time permitted. James thought it would rip and Olivia said that the popsticks would be stronger so they opted for using the popsticks instead, sticking to the original design. Adam challenged the others assumptions about paper not being strong enough. He also asked a question about whether masking tape was stronger than sticky tape. James said it would rip but Olivia said the popsticks would be sturdy enough generating a solution to solve a problem.

The children showed determination to complete the task, however James started to lose focus towards the end of the lesson. They also all had a purpose for their actions, to create a bridge that would be strong enough to hold the Three Billy Goats Gruff figurines. The finished product was original. Effective and fit for purpose.

Through the use of the Inquiry Questioning Model, the children reflected, evaluating their product after creating and testing it out.

Where to next (I Wonder):

This activity only took one session to achieve. I Wonder if it is because the children have been through the design process already or is it because this activity was easier than creating a boat that floats?

D. Research Information letter and Consent Form

Curtin University

School of Education

Stem Education in Early Childhood:

Early Childhood STEM: Digital Technologies

Dear Karen Nicholls,

My name is Chloe Oblak, and I am currently a student in Curtin University School of Education and studying for a Master of Philosophy, supervised by Associate Professor Karen Murcia. I am conducting a research project that aims to explore how children respond to the intentional inclusion of an engineering design process and how the design process effects young children's demonstration of creativity.

Why conduct this research?

Early childhood is the perfect time to cultivate positive attitudes and develop fundamental skills in STEM. In particular, the underpinning inquiry skills that young children use to investigate, design, construct and problem solve. Through introducing STEM concepts in early childhood, dispositions for learning in these areas are more likely to be carried on into adolescence and young adulthood. Also, creativity should be fostered from early childhood through to adolescence in order for individuals to develop into creative adults. The proposed study aims to add to the growing knowledge of STEM education, the engineering design process and creativity in early childhood, which will hopefully provide information and inspiration to other practitioners, providing strategies for incorporating STEM engineering in their curriculum and strategies to foster young children's creativity. As I am the children's educator, the research that I conduct will inform my practice and aims to improve learning outcomes for the children.

What does participation in this research project involve?

Participation in the project will include observation of the children in the existing environment and how they interact with the resources (e.g. Building blocks, construction materials etc.) in the room. Then an inquiry questioning framework will be used to engage children with a design process. Through these activities the children will be encouraged to plan, create, improve and reflect on their creation. An observational checklist will be used to monitor the children's developing creativity. A photographic digital diary will be kept of the free choice and inquiry activities as well as evidence of any creativity. No photographs will be taken that identify the children, hiding their face and protecting their identity. The learning stories will be focused on the children's creative design development and shared through their learning portfolio. Audio will be recorded during the activities so conversations and language can be noted.

To what extent is participation voluntary?

Participation in this study is entirely voluntary. There is no obligation to participate in this research and there will be no consequences for not participating or withdrawing your participation at a later stage. Decisions made will not affect your relationship with Curtin University or their Staff

What will happen to the information collected?

All information collected will be handled with utmost care and only de-identified data will be stored. According to the Western Australian University Sector Disposal Authority (section 14.6.4), the data will be retained for a minimum of 7 years after publication or project completion. Electronic and paper-based data will be stored on a Curtin University office computer in a secure password protected folder and raw data will only be available to the research team.

Is privacy and confidentiality assured?

The identity of participants will not be disclosed to anyone at any time, except in the unlikely event that requires reporting under the Department of Education Child Protection policy, or where the researcher is legally required to disclose that information. Participant privacy and the confidentiality of information disclosed by participants, is assured at all other times.
The data will be used only for this research project, and will not be used in any extended or further research without first obtaining explicit written consent from participants.

Is this research approved?

Curtin University Human Research Ethics Committee (HREC) has approved this study (HREC number HRE2018-XXXX). Should you wish to discuss the study with someone not directly involved, in particular, any matters concerning the conduct of the study or your rights as a participant, or you wish to make a confidential complaint, you may contact the Ethics Officer on (08) 9266 9223 or the Manager, Research Integrity on (08) 9266 7093 or email hrec@curtin.edu.au.

Who do I contact if I wish to discuss this project further?

If you would like to discuss any aspect of this study with the researchers, please do not hesitate to contact them as outlined below. If you wish to speak with an independent person about the conduct of the research, please contact Curtin University's Human Research Ethics Committee.

How do I indicate my willingness to be involved in this project?

If you have had all questions concerning this project answers to your complete satisfaction and you are willing to participate, please complete the Consent form on the following page and hand it to Chloe Oblak**.**

This information letter is for you to keep.

Thank you very much.

Kind regards

Chloe Oblak
Master of Philosophy (Education) Student
Curtin University Early Childhood Centre

Dr. Karen Murcia
Associate Professor
Curtin University School of Education
karen.murcia@curtin.edu.au
92662150

Curtin University
School of Education

Consent Form

- I have been given clear written information and I understand the intentions of this study.
- I have taken the time to consider participation in this study.
- I have had the opportunity to ask questions and had them answered to my satisfaction.
- I am agreeable to be recorded (audio of workshops and/or photographs of teaching and video recording).
- I understand that the results of this study may be presented at national and international conferences and published in peer-reviewed professional journals.
- I understand that as a participant, I will not be identifiable in any report, presentation or publication.
- I understand that I may withdraw from this research at any time without consequence.
- I know that I can contact the principal researcher, Chloe Oblak, if I have questions or concerns.
- I am aware that in the event of a complaint regarding the conduct of this study, I can contact the Curtin University Human Ethics Committee as outlined in the information letter.

Signature ………………………………………………………………… Centre Director Participant

Signature …………………………………………………………………. Researcher

Date ………………………………………………………………….

Curtin University
School of Education

Stem Education in Early Childhood:

Exploring STEM with a Focus on Engineering and Creativity in an Early Childhood Setting

Dear Parent/Guardian,

My name is Chloe Oblak, and I am currently a student in Curtin University School of Education and studying for a Master of Philosophy, supervised by Associate Professor Karen Murcia. I am conducting a research project that aims to explore how children respond to the intentional inclusion of an engineering design process and how the design process effects young children's demonstration of creativity.

Why conduct this research?

Early childhood is the perfect time to cultivate positive attitudes and develop fundamental skills in STEM. In particular, the underpinning inquiry skills that young children use to investigate, design, construct and problem solve. Through introducing STEM concepts in early childhood, dispositions for learning in these areas are more likely to be carried on into adolescence and young adulthood. Also, creativity should be fostered from early childhood through to adolescence in order for individuals to develop into creative adults. The proposed study aims to add to the growing knowledge of STEM education, the engineering design process and creativity in early childhood, which will hopefully provide information and inspiration to other practitioners, providing strategies for incorporating STEM engineering in their curriculum and strategies to foster young children's creativity. As I am the children's educator, the research that I conduct will inform my practice and aims to improve learning outcomes for the children.

What does participation in this research project involve?

Participation in the project will include observation of your child in the existing environment and how they interact with the resources (e.g. Building blocks, construction materials etc.) in the room. Then an inquiry questioning framework will be used to engage children with a design process. Through these activities your child will be encouraged to plan, create, improve and reflect on their creation. An observational checklist will be used to monitor your child's developing creativity. A photographic digital diary will be kept of the free choice and inquiry activities as well as evidence of any creativity. No photographs will be taken that identify your child, hiding your child's face and protecting their identity. The learning stories will be focused on your child's creative design development and shared through their learning portfolio. Audio will be recorded during the activities so conversations and language can be noted.

To what extent is participation voluntary?

As practitioner researcher, I will be conducting normal care and education practices with your child as well as focussing on the introduction of the inquiry questioning design model. There is no obligation for your child to participate in this research and they will still have access to the activities as they will be integrated into the normal daily program. Furthermore, there will be no consequences for withdrawing your child's participation at any stage prior to any formal publications. Decisions made will not affect your relationship with your child's Child Care Centre, Educator or Curtin University Staff.

What will happen to the information collected?

All information collected will be handled with utmost care and only de-identified data will be stored. According to the Western Australian University Sector Disposal Authority (section 14.6.4), the data will be retained for a minimum of 7 years after publication or project completion. Electronic and paper-based data will be stored on a Curtin University office computer in a secure password protected folder and raw data will only be available to the research team.

Is privacy and confidentiality assured?

The identity of participants will not be disclosed to anyone at any time, except in the unlikely event that requires reporting under the Department of Education Child Protection policy, or where the researcher is legally required to disclose that information. Participant privacy and the confidentiality of information disclosed by participants, is assured at all other times.
The data will be used only for this research project, and will not be used in any extended or further research without first obtaining explicit written consent from participants.

Is this research approved?

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Curtin University Early Childhood Centre

<u>Contacts</u>

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Associate Professor
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92662150

Karen Nicholls
Centre Director
Curtin University Early Childhood Centre
karen.nicholls@curtin.edu.au
92667459

Consent Form

- I have been given clear written information and I understand the intentions of this study.
- I have taken the time to consider my child's participation in this study.
- I have had the opportunity to ask questions and had them answered to my satisfaction.
- I am agreeable to activities involving my child being recorded (photographs and audio recording of teaching activities).
- I understand that the results of this study may be presented at national and international conferences and published in peer-reviewed professional journals.
- I understand that as a participant my child will not be identifiable in any report, presentation or publication.
- I understand that I may withdraw my child from this research at any time without consequence.
- I know that I can contact the principal researcher, Chloe Oblak (9266 7459), if I have questions or concerns.
- I am aware that in the event of a complaint regarding the conduct of this study, I can contact the Curtin University Human Ethics Committee as outlined in the information letter.

Signature ………………………………………………………………… Parent

Date ………………………………………………………………….

Signature Researcher

(Chloe Oblak)