# Educators as Co-Designers:
# A Collaborative Inquiry into Early Childhood Computational Thinking and Purposeful Robotic Play

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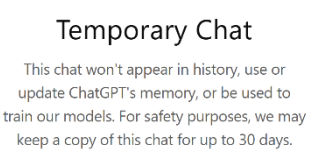
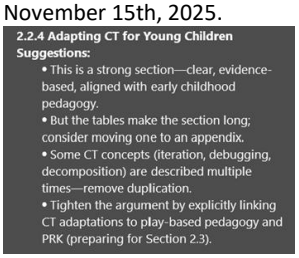
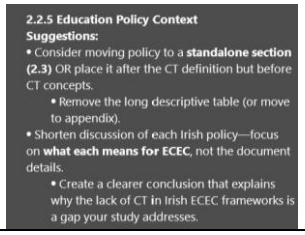
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December 2025

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# List of Abbreviations

| | |
|---|---|
| **CT** | Computational Thinking |
| **DCEDIY** | Department of Children, Equality, Disability, Integration and Youth |
| **DCU** | Dublin City University |
| **DCYA** | Department of Children and Youth Affairs |
| **DE** | Department of Education |
| **DES** | Department of Education and Skills |
| **ECCE** | Education Early Childhood Care and Education (programme) |
| **ECEC** | Early childhood education and care |
| **EdD** | Doctor of Education |
| **EU** | European Union |
| **GoI** | Government of Ireland |
| **JCE** | Joint Committee on Education, Further and Higher Education, Research, Innovation and Science (JCEFHERIS) |
| **NCCA** | National Council for Curriculum and Assessment |
| **OECD** | Organisation for Economic Co-operation and Development |
| **PRK** | Programmable Robotic Kit |
| **STEM** | Science, Technology, Engineering and Mathematics |
| **WHO** | World Health Organisation |

# Glossary

| | |
|---|---|
| Early Childhood Care and Education (ECCE) Programme | A free, universal two-year preschool programme in Ireland available to all children aged 2 years and 8 months to 5 years and 6 months. It supports children's early learning and development before they begin primary school. |
| Early Childhood Education and Care (ECEC) | The provision of care and education for children before compulsory school age includes a wide range of services, settings, and stakeholders involved in caring for and educating babies, toddlers and young children. |
| Aistear | Ireland's Early Childhood Curriculum Framework, which guides practitioners in supporting children's holistic learning and development. |
| Digital Learning | The use of digital technologies and tools to support, enhance, and extend children's learning experiences, allowing them to explore, create, and collaborate in meaningful ways. |
| Digital Literacy | The ability to use digital tools safely, effectively, and critically for learning, communication, and creativity. It involves understanding how digital systems work and how to navigate them responsibly. |
| Digital Competence | A broader concept than digital literacy, encompassing the knowledge, skills, and attitudes needed to use digital technologies confidently, creatively, and ethically in learning and daily life. |
| Computational Thinking | A problem-solving process that involves breaking down complex problems into smaller parts, recognising patterns, creating step-by-step solutions (algorithms), and testing or improving those solutions |
| Algorithmic Thinking | The ability to formulate clear, logical sequences of steps (algorithms) to solve a problem or complete a task. |
| Pattern Recognition | Identifying similarities, trends, or regularities within data, objects, or experiences; an essential skill for logical reasoning and computational thinking. |
| Debugging | The process of finding and fixing errors or problems in a set of instructions, programme, or process to make it work correctly. |

| | |
|---|---|
| Decomposition | Breaking down a complex problem or task into smaller, more manageable parts to make it easier to understand and solve. |
| Programmable Robotic Kit | A hands-on educational tool that allows children to build, program, and control robots using simple coding or sequencing, supporting learning in computational thinking, STEM, and collaboration. |
| Purposeful Play | A type of play that is child-led yet intentionally supported by educators to promote specific learning outcomes or developmental goals. |
| Intentional Pedagogy | An approach where educators plan, observe, and respond thoughtfully to children's interests and learning opportunities, balancing child-initiated and adult-guided experiences. |
| STEM Education | An integrated approach to learning that combines Science, Technology, Engineering, and Mathematics. In early childhood the focus is on developing curiosity, creativity, problem-solving, and inquiry skills through play and exploration. |
| Professional Learning | The ongoing process through which educators reflect on, update, and deepen their knowledge, skills, and practices to improve teaching quality and outcomes for children. |

# Abstract


**Educators as Co-Designers:**
**A Collaborative Inquiry into Early Childhood Computational Thinking and Purposeful Robotic Play**

**Anna Barr**

This study explored how early childhood educators in an Irish Early Childhood Education and Care (ECEC) setting can be supported to co-design learning experiences that foster young children's computational thinking through purposeful play with programmable robotic kits. With increasing recognition of computational thinking as a foundational element of digital literacy, there is a strong rationale for integrating programmable robotics into ECEC through developmentally appropriate, playful, and intentional pedagogies. Yet, Irish educators face barriers related to limited guidance, professional learning, and clarity on how CT aligns with child-led, play-based curricula.

Guided by an integrated theoretical framework combining constructionism (Papert, 1980), sociocultural learning theory (Rogoff, 1990), and the ECEC professional knowledge perspective (Campbell-Barr, 2019), a design-based research approach was implemented in a single ECEC setting. Through iterative, collaborative cycles of co-design, implementation, and reflection, two educators and eleven children (aged 3–5) engaged in twelve purposeful robotic play-sessions.

Reflexive thematic analysis identified three interrelated themes, Computational Thinking Co-learners, Collaborative Inquiry, and Balancing Choice and Challenge, revealing how educators' professional learning involved intertwined professional learning dimensions of *knowing what* (conceptual understanding of CT), *knowing how* (pedagogical enactment), and *knowing why* (value alignment and reflective intentionality). The study establishes that these dimensions are best supported through a 'learning ecology' defined by the newly developed SEA Framework of Structural, Experiential and Attitudinal Supports and the DISC Framework for Collaborative Inquiry in Designing Early Childhood Computational Thinking Learning Experiences.

The study contributes a model of professional learning for computational thinking pedagogy that situates educator development within an ecology of reflective, collaborative, and practice-embedded inquiry. The findings offer a foundation for professional learning design, curriculum development, and policy initiatives to establish digital literacy and computational thinking within early childhood education and care.

# Chapter 1: Introduction

There is growing recognition that digital technologies are part of young children's everyday lives and should therefore be integrated into Early Childhood Education and Care (ECEC) as part of fostering digital literacy (European Commission, 2015; OECD, 2023). Since 2017, policy discourse has shifted focus from *whether* digital technologies should be integrated into ECEC to *how* and *why* they should be integrated. International policy reports now position digital literacy as a key competence that begins in early childhood and should be supported through play-based learning experiences (OECD, 2023; Dardanou et al., 2023). Within this broader digital literacy agenda, computational thinking (CT) is increasingly recognised as an important component (OECD, 2023; Dardanou et al., 2023). CT aligns with problem-solving, reasoning, and inquiry that are well suited to early childhood pedagogy and can support children's holistic learning and development (OECD, 2023; Bers et al., 2022).

Although international recommendations suggest that young children should have opportunities to develop Computational Thinking (CT) as part of building digital literacy, educators in Ireland face significant barriers as CT in ECEC is still not explicitly addressed in Irish education policy. Irish policy has begun to acknowledge digital literacy and the role of digital technologies, particularly through STEM initiatives, however there is a lack of practical guidance, and few professional learning opportunities for integrating digital technologies into ECEC. National reviews and strategies highlight that successful implementation depends on educators' knowledge, skills, and values in relation to STEM, digital literacy (which includes CT) in order to make informed, confident pedagogical decisions, but also acknowledge that significant gaps persist (DE, 2020; French and McKenna, 2022; GoI, 2023; 2024).

This study responds to that gap through a design-based research intervention designed to support early childhood educators in co-designing purposeful play experiences for children aged 3–5, using programmable robotic kits (PRK) to foster computational thinking (CT) within an Irish ECEC setting. By focusing on educators' professional learning and practice, the study explores what conditions and supports are needed to move from policy aspirations about digital literacy and CT to designing meaningful experiences for young children. This chapter outlines the challenges of enacting curriculum and practice to support young children's development of digital literacy, and, more specifically computational thinking, in ECEC. It examines relevant national and international policy, presents my rationale and positionality for the research, and sets out the aims, questions to be addressed and methodology underpinning the study. The chapter concludes with an outline of this dissertation structure.

## 1.1 Policy Context-Digital Literacy in ECEC

Over the last decade, there has been a growing recognition that digital technologies are part of young children's lives and should therefore be integrated into ECEC as part of fostering young children's digital literacy. In the context of this study, digital literacy is understood as young children's emerging ability "to use digital technologies for play, self-expression and learning; and …computational thinking" (OECD, 2023, p. 29). The concept of computational thinking (CT) refers to ways of solving problems that involve debugging and creating step by step instructions and sequences through algorithmic thinking and pattern recognition (Bers et al., 2022) and will be discussed in Section 2.2. In this study, computational thinking in early childhood is understood as emerging through purposeful play, where child-led, hands-on engagement with meaningful tools, programmable robotic kits, is supported by educators through responsive scaffolding and guided participation (Ackermann, 2003; Rogoff, 2003). Purposeful play refers to child-

led play that is intentionally co-constructed and supported by educators to promote specific learning outcomes or developmental goals (Fleer, 2011; French and McKenna, 2022). Within early childhood education and care, play can be conceptualised as a continuum ranging from child-initiated free play through guided play to more structured, educator-led playful experiences (Wood, 2013). Purposeful play is situated between guided and educator led play providing valuable opportunities to support conceptual understanding through children's playful exploration and discovery, as will be explored in more detail in Section 2.4. As such, purposeful playful, hands-on activities with programmable robotic kits are well suited to supporting children's development of CT (OECD, 2023).

### *1.1.1 International Developments*

The European Commission's *Young Children (0–8) and Digital Technology* report (2015; 2018) recommends that EU member states encourage ECEC settings "to take a more active role in promoting creative and educational uses of digital technologies…" (p. 31). More recently the OECD (2023) report: *Empowering Young Children in the Digital Age,* highlighted the importance of incorporating digital literacy into the ECEC curriculum and aligning national curricular frameworks with digital learning goals and guidelines. The OECD (2023) clearly states that "for children, acquiring both digital literacies, in general, and computational thinking, in particular, consists of becoming empowered users of digital technologies," (p. 111) is vital for future citizenship and workforce participation. Thus, reinforcing the importance of beginning CT opportunities in ECEC rather than waiting until primary school and beyond. In addition, introducing "computational thinking education in early childhood may avoid future challenges associated with introducing these skills in later years" (Bers et al., 2022, p. 5).

### *1.1.2 National Policy Developments*

While international policy (OECD, 2023; JRC, 2018) increasingly supports the integration of digital technologies and computational thinking in early childhood education, Irish education policy is still developing in this area (DE, 2020). Recent documents (Table 1) indicate growing momentum, with calls for digital literacy to begin in ECEC from the age of three in order to build digital-age competencies, promote equity, and ensure continuity into primary education (DE, 2017; 2022; GoI, 2023b; 2024; JCE, 2023; NCCA, 2023). Purposeful, hands-on play and intentional pedagogy are recognised as effective approaches for supporting digital literacy and engagement with digital technologies (French and McKenna, 2022; NCCA, 2024). However, successful implementation depends on educators' knowledge, skills, and values; areas where significant gaps persist (French and McKenna, 2022; DE, 2023; GoI, 2023a). National recommendations emphasise the importance of professional learning and partnerships with networks such as higher education institutions, which can provide role models and expert support (GoI, 2023a).

Ireland's policy discourse increasingly reflects the international priorities (Table 1). Since 2017, government strategy documents have moved towards positioning digital literacy as a core digital-age competency that should begin developing in ECEC (DE, 2017; 2020). *The STEM Education Policy Statement 2017–2026* (DE, 2017) acknowledges the role of STEM, including digital technologies, in fostering these skills from early childhood. The updated *Literacy, Numeracy and Digital Literacy Strategy 2024–2033* (GoI, 2024) builds on this, recognising digital literacy as an essential skill needed "to thrive and flourish as an individual, to engage and contribute fully as an ethical, active member of society and to live a satisfying and rewarding life" (p. 22). Recent initiatives, such as the *First 5: Implementation Plan 2023–2025* (GoI, 2023b, 2024) and the *STEM Education*

*Implementation Plan to 2026* (GoI, 2023a), further commit to developing policy and professional learning to support digital technology integration in ECEC.

**Table 1: Irish ECEC Digital learning and Digital Literacy Policy Context 2017-2025**

| Irish ECEC Digital Learning and Digital Literacy Policy Context 2017-2025 | | |
|---|---|---|
| **Year/ Body** | Document | Key position/ question/ recommendation |
| **DES, 2016** | *Action Plan for Education 2016-2019* | ECEC is included in relation to raising quality and minimising disadvantage – no mention of STEM or digital learning in ECEC |
| **DES, 2016** | *STEM Education Consultation Report 2017* | No mention of ECEC-consultation focused on Primary and Post-primary |
| **DE, 2017** | *STEM Education Policy Statement 2017-26* | Positions STEM in ECEC as a means to develop 21st-century skills and reduce disadvantage. |
| **DE, 2020** | *Digital Learning 2020: Reporting on practice in Early Learning and Care, Primary and Post-Primary Contexts* | Questions use of DT with young children; notes educator uncertainty. |
| **DE, 2022** | *Digital Strategy for Schools to 2027* | Recognises digital literacy begins in early childhood but does not outline how it should be enacted. |
| **NCCA, 2023** | *Primary Curriculum Framework For Primary and Special Schools* | Acknowledges digital competencies from ECEC carry into primary education; but does not outline how it should be enacted. |
| **JCE, 2023** | *The Oireachtas report on The Future of Science, Technology, Engineering and Maths (STEM) in Irish Education* | Recommends embedding STEM education within *The ECCE Programme. However no plan outlined.* |
| **DE, 2023** | *Recommendations on STEM and the Arts in Education* | Calls for professional learning to build ECEC educator capacity. |
| **GoI, 2023a** | *STEM Education Implementation Plan to 2026* | Recommends professional learning to develop ECEC educator pedagogical content knowledge. |
| **GoI, 2023b** | *First 5: Implementation Plan 2023-25 update* | Commits to a policy statement on digital learning and the use of DT in ECEC. |
| **GoI, 2024** | *Ireland's Literacy, Numeracy and Digital Literacy Strategy 2024-2033* | Recognises digital literacy as an essential skill however no strategy on how to enact it within ECEC. |
| **NCCA, 2024** | *[Updated] Aistear: The Early Childhood Curriculum Framework* | Recognises the value of DT; play with DT should be hands-on, purposeful, and embedded within broader pedagogical goals. |

As illustrated in Table 1, ECEC did not feature in any national STEM policy documents before 2017; STEM policy discourse and initiatives were confined to the primary and post-primary sectors. Following ECEC's inclusion in the first Irish *STEM Education Policy Statement 2017–2026*, there has been a rapid inclusion of references to STEM, digital literacy and digital technology use in ECEC policy texts. However there has been limited guidance materials and professional learning opportunities to support the enactment of STEM education and digital literacy in ECEC. Taken together, these developments illustrate a rapidly shifting landscape in which STEM, and digital literacy, are being positioned as important to ECEC (Figure 1). However, having policy documents that mention STEM and digital literacy in ECEC is only one step; what is still unclear is how these ideas can be meaningfully enacted in ECEC. This highlights the timeliness of this study, as it focuses on what educators need, in terms of support, professional learning and practical approaches, to translate STEM and digital literacy policy into embedded everyday ECEC practice.

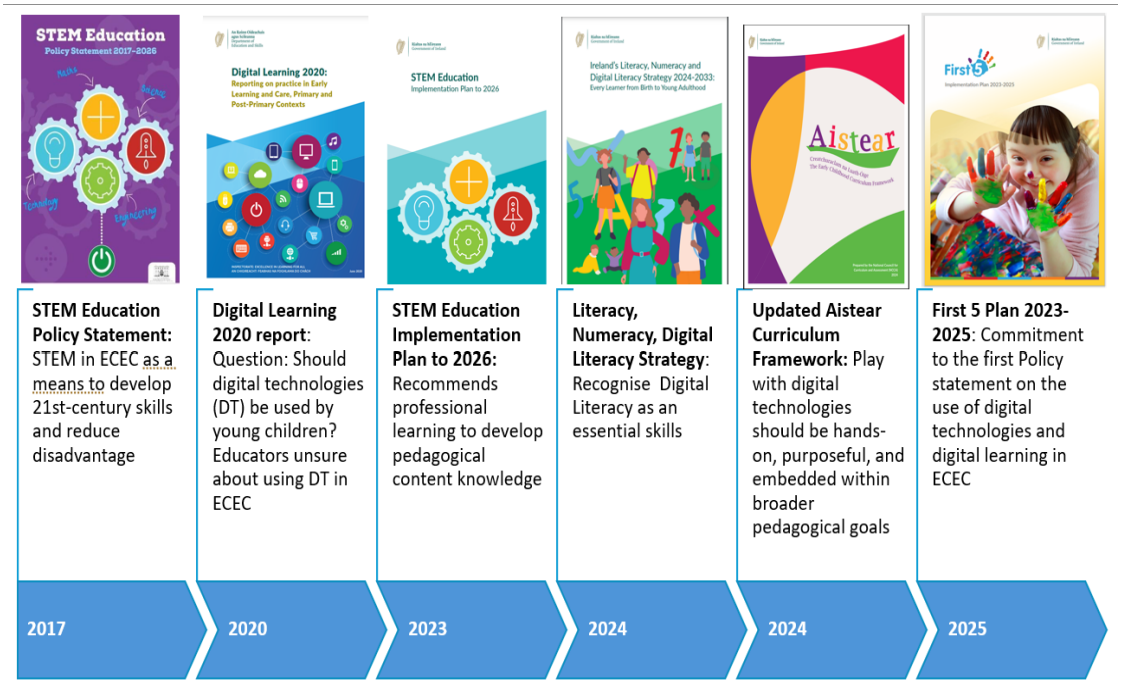



**Figure 1 Evolving National ECEC Policy 2017-2025**

### *1.1.3 Equity and the Digital Divide*

The OECD (2023; 2025) identifies mitigating the digital divide as a key challenge for ECEC, noting disparities in children's access to quality digital resources, variation in digital support at home, and differences in readiness between ECEC settings. Equity concerns are also central to Irish policy: the STEM Education Implementation Plan to 2026 (GoI, 2023a) states that all children, regardless of background, gender, or ability, should have access to digital literacy development from early childhood through post-primary education. *The Literacy, Numeracy and Digital Literacy Strategy 2024–2033* (GoI, 2024) echoes this, emphasising the need for effective transitions so that children can build on the digital literacy skills acquired at home and in ECEC as they progress through the education continuum.

### *1.1.4 Bridging Home and School*

ECEC, and in particular the government funded Early Childhood Care and Education (ECCE) programme, is uniquely positioned to bridge the digital experiences children have at home with the digital learning expectations they will encounter in primary school (Figure 2). The ECCE programme is a universal preschool scheme that provides up to two years of free, part-time early learning for children from 2 years and 8 months to 5 years and 6 months. The recent *An independent review of the ECCE programme in Ireland* (Walsh et al., 2024) notes that about 96% of eligible children avail of at least one year of ECCE. Focusing on educators and children within this programme is therefore well justified as they represent the majority of the cohort transitioning to primary school (O'Kane, 2016).




***Figure 2 ECEC as a Bridge Between Digital Lives from Home and Primary Education***

By supporting digital literacy development from the earliest years, ECEC can help close the digital divide and ensure equitable opportunities for all learners. Research identifies that digital literacy and competence begin well before formal schooling. The Aistear literature review (French and McKenna, 2022) describes today's youngest learners, sometimes called "Digitods" (p. 117), as actively engaging with technology, particularly touchscreens, from as young as six months old, with "increased access to smart devices…" and "…diverse digital content" (p. 30). Consequently, they bring "funds of knowledge and experiences of digital technology use" (p. 117) from their digital lives at home into their early childhood settings. Recognising and building on these digital funds of knowledge, children's everyday experiences, interests and skills with technology, discussed in more detail in Chapter 2, is important, especially as digital literacy and competence are understood to begin well before primary school (Butler and Leahy, 2022). In addition, An Independent Review of the ECCE Programme in Ireland (Walsh et al., 2024) reported that most settings actively nurture children's "positive learning dispositions and skills e.g. independence, communication, problem solving, early numeracy" (p. 132). This indicates that the programme is well placed to support the development of skills aligned with computational thinking and digital literacy.

### *1.1.5 Bridging the Policy Gap*

Although Irish ECEC policy is beginning to reflect the view that digital literacy and STEM-related skills begin in the early childhood and that ECEC plays a key role in supporting this development, there is still a long way to go in developing seamless transition from ECEC to Primary school. *The STEM Education Policy Update* (GoI, 2023a) committed to developing a digital learning policy statement for ECEC, a priority that has since been integrated into the *First 5: Implementation Plan 2023–25* (GoI, 2023b, 2024). *The Primary Curriculum Framework* (NCCA, 2023) positions digital learning as a core competence across all primary classes, explicitly acknowledging the digital

competencies children bring from their home and ECEC experiences. Its close alignment with the updated *Aistear Early Childhood Curriculum Framework* (NCCA, 2024) strengthens continuity by valuing play-based, engaging learning and introduces a disposition-based competency, 'being a digital learner', which encourages children to become "curious, creative, confident and critical" users of technology (NCCA, 2023, p. 10). *The STEM Education Implementation Plan to 2026* (GoI, 2023a) and the *Primary Curriculum Framework* (NCCA, 2023) both stress the importance of continuity in digital literacy development during the transition from preschool to primary school (GoI, 2023a, p. 5). The Oireachtas report *The Future of STEM in Irish Education* (2023) goes further, recommending that STEM education be embedded in the ECCE programme. Given that 96% of children in Ireland participate in the ECCE Programme before starting primary school (Walsh et al. 2024), such integration has significant potential to promote equitable digital opportunities. While the ECCE Review (Walsh et al. 2024) recognised the sector's potential to foster foundational cognitive and problem-solving skills, it noted that collaboration between ECEC and primary settings in curricular and pedagogical planning remains underdeveloped. Strengthening such links could enhance continuity in how children's digital and inquiry-based competencies are supported between ECEC and primary education.

## 1.2 Curriculum Context – Digital Literacy and Computational Thinking

The OECD (2023) emphasises the need for national curriculum frameworks to integrate both digital literacy and computational thinking (CT) from early childhood, arguing that these skills are best developed before primary school. While Ireland's early childhood curriculum framework does not explicitly use the term computational thinking, both its structure and pedagogy align closely with CT-related concepts, particularly in the updated *Aistear Early Childhood Curriculum Framework* (NCCA, 2024). Table 2 compares

curriculum language in relation to digital technology across the two versions of Aistear, 2009 and 2024, illustrating a shift toward digital literacy and alignment with CT practices.

**Table 2: Aistear's Framing of Digital Technologies 2009 versus 2024**

| Area | Aistear (2009) | Aistear (2024) | CT Alignment with Aistear (2024) |
|---|---|---|---|
| **Technology Terminology** | Information and Communication Technology (ICT) | Digital technologies | Broader framing supports CT integration through STEM and inquiry learning |
| **Technology Focus** | Devices as tools to communicate information | Digital tools as supports for holistic learning and development | Supports CT through problem-solving, reasoning |
| **Technology Concepts** | Does not explicitly acknowledge | Technology as an early STEM concept- Both plugged (Robotics) and unplugged (real world digital tools) | Lays the foundation for digital literacy and mathematical skills such as problem-solving, sequencing and spatial reasoning |
| **Play context** | Does not explicitly acknowledge play with use of digital tools | Positions play with digital technologies as hands-on, purposeful, and reflective | Encourages playful exploration of CT-related skills |
| **Skills development** | Learning goals include | Learning goals include predicting, problem-solving, analysing, reasoning, and justification | Aligns with OECD/ Bers et al. (2022) CT skill sets without naming CT explicitly. |
| **Learning dispositions** | Limited reference to technological/ mathematical exploration | Explicit recognition of enjoyment in exploring STEM concepts | Embeds inquiry-based CT thinking- children as thinkers: question, investigate, discover |

The first iteration of *Aistear: The Early Childhood Curriculum Framework* (NCCA, 2009) referred to technology primarily as "Information and Communication Technology (ICT)," with an emphasis on using devices to "communicate and manipulate information" (p. 55) and to "broaden understanding of the world" (p. 35). While it briefly mentions digital technology as an assistive tool, it offers limited guidance on its broader use or any clear "expectations for digital learning" (DE, 2020, p. 6). It does not explicitly recognise that children play with digital technologies; however, it does acknowledge that children imagine, create, and collaborate through play; principles that could be extended to digital contexts. In contrast, the updated *Aistear* (NCCA, 2024) marks a significant shift. It

recognises the value of digital technologies in supporting holistic learning, acknowledges children's enjoyment of exploring STEM concepts, and introduces learning goals that align with CT-related skills such as problem-solving, predicting, analysing, reasoning, and justification, particularly within the Exploring and Thinking theme. While 'computational thinking' is not explicitly named, its principles are embedded throughout, with digital learning situated in a play-based, child-centred pedagogy. The framework promotes interactive and reflective uses of digital technologies, positioning play-based, hands-on, and inquiry-oriented learning at the heart of early childhood education.

The *Aistear* (NCCA, 2024) guidelines emphasise that play with digital technologies should be reflective, purposeful, and integrated with broader pedagogical goals. For example, French and McKenna (2022) note that that while young children are naturally curious, "these skills do not persist without appropriate support, encouragement, and experiences that sustain children's interest and investigation" (p. 226). Therefore, the literature review (French and McKenna, 2022), which informed the development of updated *Aistear* framework (NCCA, 2024) emphasises guided play and intentional pedagogy as important for sustaining children's curiosity and developing higher-order thinking.

Intentional pedagogy is defined as educators' responsive and reflective actions to notice and support emerging strengths and questions through cycles of noticing, nurturing, responding, and reflecting (NCCA, 2024). Play remains central: whether free, guided, or educator-led, it provides opportunities to integrate digital tools meaningfully into problem-solving, concept development, and creative exploration (OECD, 2023). Intentional pedagogy, enacted through purposeful play, provides a means of guiding learning towards specific goals and is especially effective in promoting CT and higher order thinking in early learners (Bers et al, 2022; French and McKenna, 2022).

### *1.2.1 Curriculum as a Bridge*

Together, these suggested curricular and pedagogical shifts position Irish ECEC to bridge children's home-based digital experiences with primary school expectations, supporting equitable access to digital literacy and the foundations of computational thinking. Findings from the *Independent Review of the ECCE Programme in Ireland* (Walsh et al, 2024) indicate that the ECCE programme offers an appropriate learning environment for introducing programmable robotic kits (PRK) and computational-thinking activities for young children. However, the evaluation notes that although cognitive development is valued by educators', their capacity to ensuring higher levels of challenge and extend children's higher order thinking through play and playful pedagogies "may require further consideration" (pp. 236). As such the report recommends "enhancing access to quality professional development opportunities" (p. 238) to enable educators embed such pedagogies effectively into their practice.

## 1.3 Practice Context – Challenges and Opportunities for Educators

Although international policy guidance highlights the importance of young children having opportunities to develop their CT as part of encouraging their digital literacy, there are barriers and challenges for educators in Ireland to achieve this within their ECEC practice. Reports such as *Digital Learning 2020: Reporting on Practice in Early Learning and Care, Primary and Post-Primary Contexts* (DE, 2020) highlight the absence of clear national guidance, and limited access to ongoing professional learning which constrain educators' ability to develop digital pedagogical confidence and expertise. These systemic constraints influence how educators interpret, value, and make decisions on the use of digital technologies within ECEC settings.

### *1.3.1 Pedagogical Values Tension*

The Aistear literature review (French and McKenna, 2022) highlights a tension in educators' pedagogical values regarding the role of digital technologies in early childhood education, noting that many educators feel uncomfortable with young children's interest, confidence, and desire to engage with digital technologies. This discomfort has contributed to a disconnect between the digital experiences children have at home and the opportunities provided in early childhood settings. These concerns are echoed in the *Digital Learning 2020: Reporting on Practice in Early Learning and Care, Primary and Post-Primary Contexts* (DE, 2020), which found that, at the time, "consideration of the appropriate use of digital technologies has only just begun" (p. 5) in ECEC. The report even questioned "whether… digital technology should be used by young children" (p. 23). As such, educators have often assumed the role of gatekeepers, limiting young children's engagement with digital tools (French and McKenna, 2022). This presents two key issues. First, it overlooks children's lived experiences and interests in digital technologies within ECEC settings. Second, it contributes to a lack of continuity in children's digital literacy development as they transition from home to preschool and then to primary school.

### *1.3.2 Knowledge and Skills Gap*

Even where educators are open to digital integration, many lack the pedagogical knowledge and technical skills to use digital technologies as part of purposeful play. The *Digital Learning 2020: Reporting on Practice in Early Learning and Care, Primary and Post-Primary Contexts* noted that many were "unsure as to how to approach digital learning in a way that was appropriate to the age of their learners" (p. 6). French and McKenna (2022) note that, while intentional pedagogies and guided play are effective approaches, they can "be at odds with well-established play pedagogy prevalent in many early childhood approaches" (p. 229), which often position the educator primarily as an

observer during children's free play. To effectively support children's development of computational thinking (CT), educators must develop their own subject-matter knowledge and pedagogical content knowledge to help children develop "scientific skills such as problem-solving and critical thinking" (French and McKenna, 2022, p. 227). Recent STEM Education updates (GoI, 2023a; DE, 2023) recognise these challenges and emphasise the need for both initial and ongoing professional learning opportunities that build "knowledge (knowing what), skills (knowing how), and values (knowing why)" (DE, 2023, p. 8). These three interrelated dimensions are illustrated in Figure 3.

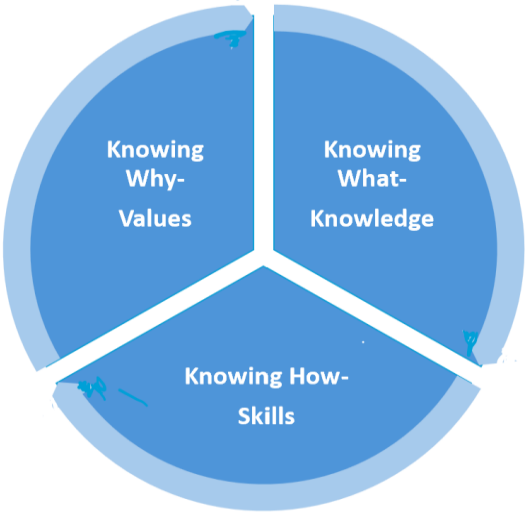



**Figure 3: Dimensions of Knowledge: Knowing What-Knowing How-Knowing Why (adapted from DE, 2023, p.8)**

There is broad agreement that research is needed to help educators make informed choices about promoting "meaningful and relevant uses of digital technologies from an early age" (Butler and Leahy, 2022, p. 54). This includes research that identifies effective pedagogical strategies (GoI, 2024), investigates appropriate types of technology, usage times, and purposes (Butler and Leahy, 2022), and defines what constitutes good practice (DE, 2020). Supporting educators to develop both subject matter knowledge and pedagogical content knowledge through initial teacher education and ongoing professional learning is identified as essential (GoI, 2023a).

## 1.4 Rationale and Positionality

My interest in this research stems from both professional and personal experience. I currently lecture on an Early Childhood Education and Care (ECEC) degree programme at the National College of Ireland, specialising in curriculum, pedagogy, and play, and more recently teaching modules on digital play and early learning in a digital world. This role has involved introducing digital technologies and play experiences to educators who are completing their degrees while working in early childhood settings, giving me direct insight into their challenges, concerns, and the pedagogical value they assign to these experiences. Prior to lecturing, I worked as an early childhood educator for five years until 2016. At that time, I often felt hesitant to introduce digital technologies to young children due to a lack of clear guidance, resources, and policy support. In contrast, as a parent, I actively encouraged my own children to engage with digital technologies from an early age. This disconnect between my personal and professional approaches gave me a shared understanding for current educators and a motivation to help bridge the support gap I had experienced.

By 2020, in my academic role, I observed a notable shift in the literature and professional discourse, from questioning whether children 'should' engage with digital technologies in ECEC settings, to 'how' should children engage with digital technologies (Bird and Edwards, 2015; Sakr, 2020). This was the point at which I applied to undertake a Doctor of Education at Dublin City University, aiming to engage in research that would underpin and inform practical guidance for educators on facilitating purposeful digital play.

The first two years of my doctoral study were spent examining national and international policy developments, key concepts in digital literacy and computational thinking (CT), and literature on play with programmable robotic kits (PRK) in early childhood. The OECD report (Bers et al., 2022) was particularly influential in shaping my focus. As my research progressed, I narrowed my scope from digital play in general to purposeful play

with PRK as a means of supporting young children's CT and digital literacy. Through this process my positionality was informed by an integrated theoretical perspective that combines three complementary lenses: constructionism (Papert, 1980; 2000), sociocultural learning theory (Rogoff, 1990; 2003), and the early childhood professional knowledge perspective (Campbell-Barr, 2017; 2019) which are discussed in detail in Chapter 2. Together, these perspectives provide a coherent lens to examine how knowledge is constructed through play, interaction, and reflection, both for children developing CT and for educators developing CT pedagogy through co-design. I also engaged with theories of technology acceptance and models for change, which informed my decision to design the study as a collaborative process with educators, reflecting my positionality as a researcher–mentor who works alongside educators. This positionality is explored further in Chapter 3.

### *1.4.1 Research Problem*

Although young children should have opportunities to develop Computational Thinking (CT) as part of building digital literacy, educators in Ireland face significant barriers to implementing CT-focused learning experiences. These include a lack of clear policy, limited practical guidance, and few professional learning opportunities for integrating digital technologies into ECEC. These gaps affect educators' knowledge, skills, and values, which impacts their confidence and competence to make informed decisions about embedding CT in purposeful play with programmable robotic kits. This study intends to address these challenges through a design-based research (DBR) intervention in one ECEC setting. DBR is well suited to this context because it fosters collaboration between researchers and practitioners to co-design innovations that directly enhance educational practice (Philippakos et al., 2021). In addition, the DBR process is iterative, with changes to CT-focused practice shaped by both children's engagement and educators' feedback and reflections.

As illustrated in Figure 4, the DBR intervention is a cyclical process of co-design, implementation, observation, reflection, and refinement. Each phase informs the next, allowing theory and practice to evolve together through researcher–educator collaboration.

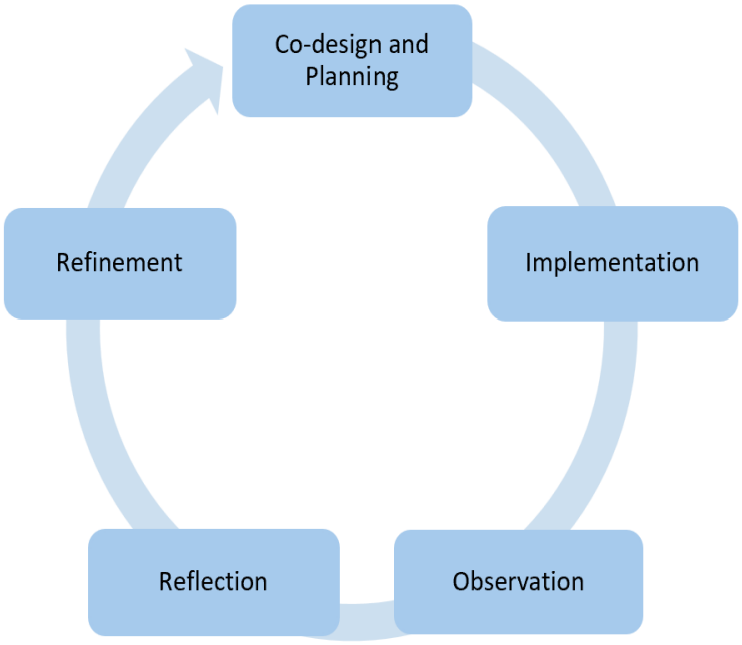



**Figure 4: Design-Based Research (DBR) Intervention Cycle (adapted from Philippakos et al., 2021)**

The co-design and planning phase focus on developing purposeful play activities using PRK. During implementation, the educators facilitate these activities with the children in their ECEC setting with my support as researcher-mentor. Observation and reflection provide opportunities to analyse how the children demonstrate CT skills and how the educators interpret and support these moments in practice. In the refinement phase, the activities and pedagogical strategies are collaboratively revised for the next iteration. This cycle embodies a core principle of DBR: that learning, teaching, and research are mutually generative within authentic educational contexts. This iterative structure is echoed in the conceptual framework presented in Chapter 2, which places the design cycles within the broader theory and context of the study.

## 1.5 Research Aims and Objectives

The aim of this study is to support educators in one early childhood setting to co-design and implement purposeful play experiences using programmable robotic kits (PRK) to foster young children's computational thinking (CT).

**Objectives**

1. Identify features of this design-based research (DBR) approach that could inform the design of professional digital learning programmes for early childhood educators.
2. Examine how the co-design process impacts educators' professional knowledge and practice in relation to CT and PRK.
3. Assess the effectiveness of purposeful play-sessions with PRK in contributing to educator's development of how to design learning activities that develop young children's CT.
4. Explore whether participation in the co-design process influences educators' beliefs about the value of CT opportunities in early childhood.

### *1.5.1 Research Question*

Based on the preceding policy analysis and identification of gaps in current research on CT in ECEC, this study is guided by the following key research question:

*What are the facilitating conditions that support early childhood educators to design learning experiences that develop young children's computational thinking through purposeful play with programmable robotics kits in an Irish ECEC context?*

A single overarching research question was used to keep the study focused on the facilitating conditions that support educators, while three sub-questions break this broad question into more manageable parts by examining what educators learn, how the co-

design supports them, and how their ECEC beliefs shape their design of purposeful CT play.

**Sub-questions**

1. *How does the co-design intervention contribute to educators' knowledge and understanding of how to develop young children's Computational Thinking using programmable robotic kits?*
2. *How do the features of the co-design intervention support educators to design learning experiences that develop young children's computational thinking through purposeful play with programmable robotic kits?*
3. *How do educators' ECEC beliefs shape their design of purposeful play with programmable robotic kits to support computational thinking development?*

## 1.6 Outline of Dissertation

This chapter has outlined the background policy context, rationale, key issues, and research aims that underpin this study. Chapter 2 provides an extended discussion of the theoretical and conceptual framework and explores four key areas within the context of early childhood education: computational thinking, digital technologies, playful learning, and educator professional knowledge and learning. Chapter Three details the methodological approach, explaining my positionality as researcher and participant, design-based research (DBR) process, data collection, analysis, and ethical considerations. Chapter Four presents and analyses the research findings and discusses them in relation to the sub-questions. Chapter Five synthesises and discusses the findings in relation to the overarching research question and, articulates design principles for supporting CT professional learning in ECEC. Chapter 6 concludes the study by outlining its contribution and implications to research, practice and policy, offering recommendations, and summarising key conclusions.

# Chapter 2: Literature Review

This chapter presents a critical analysis of the literature informing the study, which investigates how early childhood educators can design purposeful play experiences with programmable robotic kits (PRK) to support young children's development of computational thinking (CT). The review is situated within the Irish early childhood education and care (ECEC) context and responds to a growing international emphasis on fostering digital literacies, problem-solving and early STEM dispositions from early childhood (OECD, 2023, 2025). The chapter is organised into seven interrelated sections. Section 2.1 outlines the theoretical perspectives that underpin the study, drawing on constructionism (Papert, 1980, 2000, 2005) sociocultural learning approaches (Rogoff, 1990, 2003), and an ECEC professional knowledge perspective (Cambell-Barr, 2017, 2018, 2019). Together, these perspectives establish a cohesive foundation for understanding how children and educators develop computational thinking learn through purposeful play with programmable robotic kits. Section 2.2 examines computational thinking in early childhood, tracing its conceptual origins, developmental relevance, and the emerging evidence base for introducing CT in ECEC. Section 2.3 focuses on programmable robotic kits as "objects-to-think-with," (Papert, 1980, p.23) exploring how tangible technologies can mediate CT through playful, hands-on engagement. Section 2.4 examines the role of purposeful play and pedagogy, including guided play, imagination, exploration, and children's funds of knowledge shaping CT learning experiences. Section 2.5 explores educators' professional knowledge, beliefs, and learning needs, highlighting the facilitating conditions required to support educator confidence and competence when integrating CT and PRK. Section 2.6 presents the conceptual framework guiding this study, illustrating how theoretical perspectives, design-based research processes, and the Irish ECEC context interact. Section 2.7 provides a summary of key insights from the

literature. Together, these sections articulate how computational thinking can be meaningfully embedded within play-based ECEC environments through developmentally appropriate digital tools and educator-supported pedagogies. The review also identifies gaps in current policy, practice, and research, particularly the lack of guidance on CT in ECEC and limited empirical evidence on how PRK can be integrated within child-centred, play-based frameworks, thereby establishing the rationale for the present study.

## 2.1 Theoretical Perspective

This study is informed by an integrated theoretical perspective (Figure 5) that brings together Constructionism, Sociocultural learning theory, and Early Childhood Education and Care (ECEC) professional knowledge perspective. Individually, each provides a robust lens for understanding how young children and educators learn; collectively, they offer a coherent foundation for examining how computational thinking (CT) can be fostered through purposeful play with programmable robotic kits (PRK) in ECEC settings.

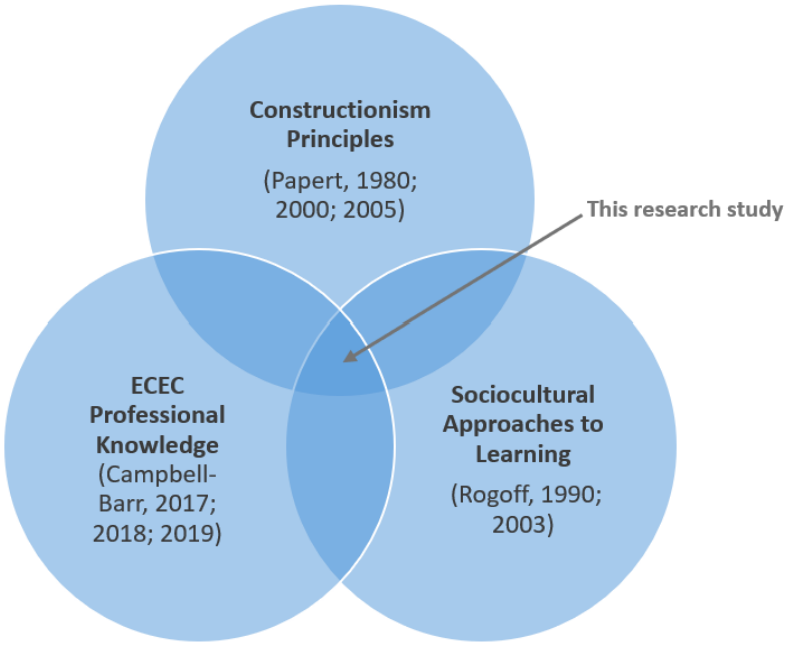



**Figure 5: Theoretical Perspective**

### Constructionism

Constructionism (Papert, 1980, 2000, 2005), positions learning as active knowledge construction, particularly effective when learners engage with tangible, personally meaningful objects. In this study, programmable robotic kits act as "objects-to-think-with" (p. 23), supporting skills such as algorithmic thinking, debugging, and pattern recognition through creative, hands-on exploration. Constructionism also frames the educators' learning as experiential: by co-designing and iterating purposeful play experiences, educators build practical and conceptual understanding of CT pedagogy through hands-on engagement. Section 2.2.3 explores constructionism in greater depth, examining how its core principles, articulated as four pillars of constructionism by Bers (2010). provide a developmentally appropriate foundation for integrating computational thinking in early childhood contexts.

### Sociocultural Learning Theory

Building on Vygotsky (1978), Rogoff's (1990; 2003) notion of guided participation, sociocultural theory frames learning as a socially mediated process occurring through guided participation in meaningful activities. Within this study, sociocultural theory is relevant at two levels:

- Between educators and children, where educators act as mediators of children's learning, scaffolding their exploration and problem-solving with PRK through modelling, collaboration, and joint activity; discussed in Section 2.4.5, p. 64.
- Between researchers and educators, where the co-design process between researcher and educators represents guided participation, a form of collaborative inquiry where knowledge and practice evolve through dialogue, reflection, and shared experience; discussed in Section 3.5.2, p. 99.

This perspective also highlights how PRK act as cultural tools that shape, extend, and mediate children's thinking, while educators' interactions shape how children make sense of computational thinking concepts.

**ECEC Professional Knowledge Perspective**

ECEC Professional Knowledge Perspective (Campbell-Barr, 2019), highlights the importance of pedagogical sensitivity and relational, developmentally appropriate practice grounded in care and communication. It positions educators' pedagogical knowledge as situated, values-based, and developed through ongoing reflection-in-action. This perspective ensures CT experiences remain aligned with early childhood values such as play, agency, and wellbeing as reflected in *Aistear the early childhood curriculum framework* (NCCA, 2024), It recognises educators as professional decision-makers whose beliefs and values shape how digital technologies are interpreted and integrated into play.

**Integrated Theoretical Lens**

When combined, these three perspectives provide a layered approach for analysing both children's CT learning and educators' pedagogical development. Constructionism explains the hands-on, object-centred nature of CT with PRK; sociocultural theory explains how learning is jointly constructed through guided participation; and the professional knowledge perspective ensures that CT experiences remain developmentally appropriate and grounded in early childhood values. Together, they support a nuanced understanding of how purposeful play with programmable robotic kits can foster computational thinking in ways that align with the goals and practices of Irish ECEC

## *2.2 Computational Thinking in Early Childhood Education and Care*

Computational thinking (CT) has become an important focus within contemporary education as societies respond to rapid technological change and the growing need for problem-solving, reasoning, and early STEM competencies. However, the concept remains characterised by definitional confusion, with no single agreed meaning, and is interpreted across disciplines in various ways, for example, as a set of programming-related skills, a problem-solving approach, or a dimension of digital literacy (OECD, 2023; Wing, 2006; Bers et al., 2022). This ambiguity is particularly evident in early childhood education and care (ECEC), where questions persist regarding what CT looks like in developmentally appropriate, play-based contexts (Hall and McCormick, 2023). In response, Section 2.2.1 reviews the conceptual foundations of CT and establishes the definition adopted within this study. Section 2.2.2 examines its developmental relevance for young children, Section 2.2.3 explores the constructionist theories underpinning its integration into ECEC, Section 2.2.4 considers how CT concepts can be adapted for early childhood contexts, and Section 2.2.5 reviews the evolving national and international policy landscape.

### *2.2.1 What is Computational Thinking?*

Computational Thinking (CT) is often understood as the ability to think in structured and logical ways, breaking down problems into smaller parts, recognising patterns, and designing step-by-step solutions (Lodi and Martini, 2021). The concept of CT was first introduced by Papert (1980) in relation to constructionist learning theory, emphasising how children construct knowledge through learning to programme devices with computing power. He viewed children's active engagement with technology as a pathway to exploring powerful ideas and engaging in new ways of thinking, discussed in more detail in Section 2.2.3. Programming and working with computers, in his view, enabled

children to construct knowledge in accessible, meaningful ways. Computers, he argued, have the potential to be "carriers of powerful ideas and cultural change" (Papert, 1980, p. 4), bringing "new opportunities for children to understand, to love, and to use ideas that had previously been inaccessible to them" (Papert, 2000, p. 722). Similarly, Wing (2006) conceptualised CT as a fundamental skill for all, defining it as a thought process involving different levels of abstraction to solve problems and think logically in the way that a computer might:

> Computational thinking involves solving problems, designing systems, and understanding human behavior by drawing on the concepts fundamental to computer science (Wing, 2006, p.33)

Her framing highlights key elements such as abstraction, decomposition, and algorithmic thinking, emphasising the systematic and transferable nature of CT across disciplines. Together, these perspectives have contributed to the understanding of CT as encompassing a broad set of skills, practices, and dispositions, including abstraction, generalisation, decomposition, algorithmic thinking, debugging, and iteration, discussed in more detail in Section 2.2.4 (OECD, 2023; Bers et al., 2022).

While these practices originate in computer science, they align closely with early childhood pedagogies that emphasise play, inquiry, hands-on exploration, meaning making and engagement with tangible tools that support early problem-solving (NCCA, 2024). In response, this study adopts a constructionist, socio-cultural and early childhood-oriented conceptualisation of CT that builds on the understandings discussed in Section 1.1 and draws on Papert's (1980; 2000; 2005) work and research in early childhood computational thinking (Bers, 2010; Pugnali, Sullivan and Bers, 2017). For the purpose of this study CT is defined as a play-based form of analytical thinking encompassing a range of problem-solving skills, dispositions, and approaches, in which children engage

with problem-solving by breaking them into smaller parts, recognising patterns, and constructing step-by-step solutions through hands-on, exploratory engagement.

This definition foregrounds how CT is experienced by young children in practice. Children engage in reasoning through problems, physically sequencing steps, testing and debugging solutions, and refining their thinking in response to outcomes, often in collaboration with peers and educators. These processes are supported through interaction with meaningful tools, such as programmable robotic kits, which function as "objects to think with" (Papert, 1980) (Section 2.2.3), enabling children to connect ideas, actions, and outcomes. As discussed in Section 1.1, computational thinking in early childhood is conceptualised as a holistic, relational, and play-based way of thinking and learning, emerging through purposeful play with programmable robotic kits and supported by educators through guided participation (Ackermann, 2003; Rogoff, 2003). The following section explores how computational thinking can foster holistic learning in young children, making it a valuable part of early childhood education.

### *2.2.2 Why Computational Thinking matters in early childhood*

CT and coding have been increasingly recognised as relevant and important "in part due to the place computers have in everyday lives" (Bers et al., 2022, p. 13), and also because of the broader need to develop skills for the digital world (OECD, 2023). In response to these trends, many countries, including Ireland have integrated CT and coding into their educational curricula at the post-primary and primary levels, while countries such as Norway, Sweden and Finland have gone further by including CT in their ECEC curricula (Dardanou et al., 2023). Most recently, the OECD (2023) recommended that all countries include CT in early childhood education and care (ECEC) national curriculum frameworks. The rationale for this is based on early childhood being a critical window for concept formation: "there can be a steep learning curve for children to acquire these

abstract concepts later in their education" (Bers et al., 2022, p. 10). It is therefore important to understand what is meant by CT in the context of ECEC. Doing so enables educators to recognise the relevance and value of creating early learning experiences that introduce and support CT in ways that are meaningful for young children in ECEC environments.

When viewed through the lens of Papert (1980), the possibilities and relevance of computational thinking (CT) in early childhood become increasingly apparent, particularly its potential to support young children's holistic learning and development by fostering new ways of thinking. This perspective moves beyond limiting CT to computer science or digital citizenship and instead positions it as a tool for cognitive and emotional growth. Papert (1980) argued that "certain uses of very powerful computational technology and computational ideas" (pp. 17–18) could significantly benefit children's thinking and learning. He believed that engaging with these tools could stimulate both cognitive and emotional development. Bers et al. (2022) support this view, noting that early childhood education and care (ECEC) settings provide "creative and exploratory time with hands-on object manipulation" (p. 11), which makes them especially well-suited to nurturing CT skills through developmentally appropriate experiences. Within this study's framing, these benefits arise specifically through children's active engagement in CT practices such as problem solving, recognising patterns and constructing step-by-step solutions within playful contexts.

The claim that CT supports the development of new ways of thinking remains debated within the literature, particularly regarding the extent to which skills transfer beyond specific contexts (Lodi and Martini, 2021). Papert's view is sometimes misinterpreted as implying that CT universally improves thinking in all domains, a kind of "automatic competence transference" (Lodi and Martini, 2021, p.899). However, this is not about

generalised developmental gains, rather, the value lies in how specific CT experiences challenge and extend children's thinking, particularly in disciplines like mathematics, science, and engineering. These are now widely recognised as foundational for early childhood STEM education and critical thinking development (GoI, 2023).

A growing body of research supports the value of CT learning experiences in early childhood, identifying several transferable learning outcomes for young learners (Lavigne, Lewis-Presser, and Rosenfeld, 2019; Nam, Kim, and Lee, 2019; Romero-Tena and Romero-González, 2020; Bers et al., 2022; Butler and Leahy, 2021). These include the development of learning dispositions such as communication, collaboration, creativity, and persistence when working through complex problems (Pugnali, Sullivan, and Bers, 2017; Lodi and Martini, 2021). In addition, the OECD (2023) identifies broader cognitive and social-emotional benefits, including improved number sense, language development, visual memory, and pro-social behaviour, particularly when CT is embedded in collaborative projects involving robotics or storytelling.

In short, CT appears to have a particularly strong impact during early childhood, a time when foundational competencies in literacy, numeracy, and social-emotional development are actively emerging. This developmental stage may offer ideal opportunity for introducing computational thinking. As such, there is increasing rationale for introducing CT before children transition to primary school. However, the OECD (2023) notes that more research is needed to strengthen the evidence base, particularly with preschool-age children. Clearer guidance is needed on the teaching and learning of CT, both conceptually and practically (Hall and McCormick, 2023), highlighting the need for deeper theoretical grounding and clearer pedagogical frameworks. To address these gaps, it is useful to return to Papert's constructionist theory, which provides a strong conceptual foundation for integrating CT into early childhood contexts. The next section

explores how constructionism can inform the design of age-appropriate, play-based learning experiences using tools such as robotics and coding.

### *2.2.3 Constructionism in ECEC*

Seymour Papert's (1980, 2000) theory of constructionism provides a meaningful theoretical foundation for introducing computational thinking (CT) in early childhood education and care (ECEC). Building on Piaget's (1952) constructivist view that children actively construct knowledge through interaction with their environment, constructionism extends this by emphasising learning through doing, creating, and playful exploration, particularly when supported by digital tools and technologies (Ackermann, 2001; Butler, 2007; Butler and Leahy, 2021). Constructionism aligns closely with early childhood pedagogy and supports the integration of technology into play-based learning in developmentally appropriate ways. It also challenges the notion that computer science is only for older learners or specific career pathways, instead framing CT as a tool for supporting new ways of thinking from a young age (Bers, 2019).

Bers (2010) articulates four core pillars of constructionism (Figure 6) that serve as a valuable framework for embedding CT into early learning environments: *learning by doing, objects to think with*, *powerful ideas*, and *self-reflection*. These pillars help educators understand how and why tools such as programmable robotics kits can be used to facilitate CT in meaningful and developmentally appropriate ways.

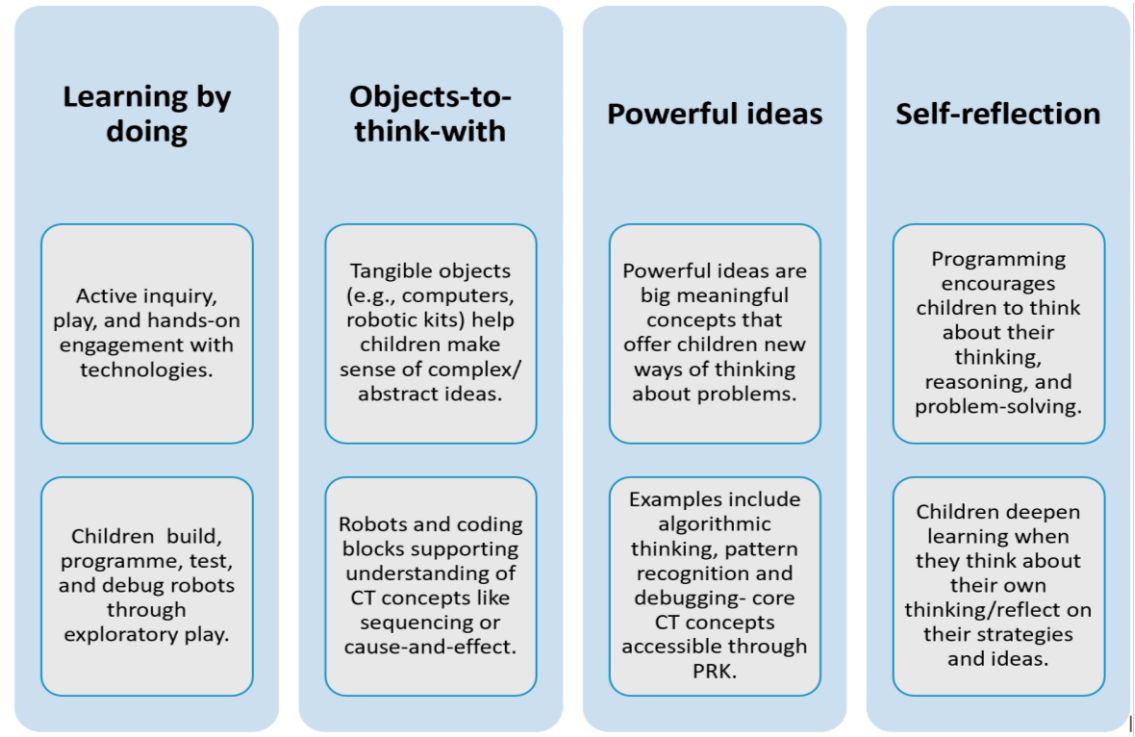



**Figure 6: Four Pillars of Constructionism (adapted Papert, 1980, 2000, 2005; Bers, 2010)**

**Learning by doing**, the first pillar, aligns closely with play-based learning in ECEC. When children interact with robotics kits, they are encouraged to explore, create, and inquire actively. This hands-on process is not only engaging but supports knowledge construction through trial and error, experimentation, and reflection, essential elements of both CT and early learning (Bers, 2010).

The second pillar, **objects to think with**, underscores the importance of tangible tools for helping children understand abstract concepts. Papert (1980) presented the idea of 'objects to think with' as purposefully chosen objects, such as computers, as "giving concrete form to areas of knowledge that previously appeared intangible and abstract" (p.23). In ECEC, tools such as programmable robots, coding blocks, or visual instruction cards help bridge the gap between abstract computational concepts and young children's hands-on learning (Bers, 2014).

**Powerful ideas**, the third constructionist pillar, refers to central computer science concepts, such as algorithmic thinking, debugging, or pattern recognition, that open up

new ways of thinking. Papert (1980; 2000) viewed devices with computing power as "carriers of powerful ideas…" (1980, p.4) coming from domains such as computer science or engineering, and through the mediation of technology these "powerful ideas could be brought into the lives of children…" (2000, p.722). Papert (2005) emphasised that computational ideas can reshape how they understand problems and make sense of the world, highlighting the transformational role of computational concepts in early learning. In early childhood contexts programmable robotic kits can act as 'objects to think' that mediate 'powerful ideas' that support young children's development of ways of thinking about complex ideas such as algorithmic thinking, or debugging (Bers, 2010). Identifying and embedding these ideas in the learning environment allows educators to design meaningful CT experiences that build on what children already know and are curious about (Bers et al., 2014).

The fourth pillar, **self-reflection**, connects closely with metacognition or thinking about one's own thinking. Programming supports metacognitive awareness by facilitating children to think about their own thinking, a point Papert (2005) argues is central to the intellectual value of early engagement with computational ideas. Bers (2010) notes CT activities encourage children to reflect on strategies, persistence, creativity, and problem-solving, supporting both cognitive and socio-emotional growth.

Together, these four pillars present constructionism as a powerful and developmentally appropriate theoretical lens for integrating CT into early childhood settings. A constructionist approach enables educators to select tools such as robotic kits not for their novelty, but for their capacity to support holistic development.

Constructionism reinforces that CT in early childhood is not merely about preparing children for future careers in technology, but an opportunity to foster new ways of thinking, creating, and making sense of the world. Papert viewed programming as a

medium for thinking about thinking, arguing that when children programme, they use computational ideas to reflect on their own thought processes, gaining insights into how they reason, problem-solve, and learn (Papert, 2005). This perspective further strengthens the relevance of constructionism for supporting CT and metacognitive development in ECEC. While constructionism offers a strong theoretical foundation, it remains essential to consider how these principles can be practically and developmentally adapted within early childhood settings.

### *2.2.4 Adapting Computational Thinking for Young Children*

Although Papert (1980) discusses computers and computational technologies, the focus of computational thinking (CT) in early childhood is not the technology itself but the mental processes involved in problem-solving. This perspective places CT within the cognitive development of young children, aligning with early learning goals that promote logical reasoning, creativity, and hands-on exploration. In many early childhood settings, CT can be introduced before any digital tool is involved. Children begin by experiencing CT through play-based exploration, learning how to break down problems, identify patterns, and sequence steps, all foundational CT concepts that support broader cognitive growth (Lodi and Martini, 2021; Bers et al., 2022). These processes reflect how CT is enacted in early childhood, through action, interaction, and iterative exploration rather than direct instruction. To clarify how CT can be developmentally appropriate for children aged 3–5, Table 3 outlines the CT concepts most commonly referenced in early childhood research and practice. These concepts allow educators to recognise that CT is not limited to screen-based or abstract coding tasks. Instead, it is a broad set of problem-solving practices that can be fostered through play, movement, collaboration, and storytelling.

**Table 3: Key Computational Thinking Concepts in Early Childhood**

| CT Concept | Definition /description<br><br>[Adapted from Angeli et al, 2016; Bers, 2010; 2022; Butler and Leahy, 2021; Heikkilä and Mannila, 2018; Lavigne et al., 2019; Lodi and Martin, 2021] |
|---|---|
| **Algorithm** | A set of defined steps to solve a problem |
| **Algorithmic thinking** | The thought process of breaking down problems into steps |
| **Algorithmic Design** | Creating the actual step-by-step solution |
| **Sequencing** | Putting steps in the correct order to complete a task or solve a problem. |
| **Abstraction** | Focusing on the important parts of a problem and ignoring unnecessary details. |
| **Decomposition** | Breaking a big problem into smaller, manageable parts. |
| **Pattern Recognition** | Spotting recurring patterns in the problem context. identify the patterns to support designing a repeatable procedure to solve the problem. |
| **Generalisation** | Using solutions or patterns from one problem to solve similar problems in new situations. For example, "I know how to make the robot turn left here, so I can use the same turn when I do another maze." |
| **Iteration** | Repeating steps to try again or improve something. |
| **Debugging** | Finding and fixing mistakes in a plan or process. |
| **Modularity** | Organising tasks or ideas into chunks that can be reused or rearranged. |
| **Conditionals** | Making decisions based on different situations (e.g., 'If this happens, then do that'). |
| **Representation** | Using pictures, symbols, or models to show a process or idea. |
| **Hardware/Software** | Understanding what a robot or computer needs to follow instructions and work properly. |

For example, activities such as giving directions for someone to reach a location in the room or using blocks to build a path for a robot can build early understanding of sequencing and debugging (Bers et al., 2022; OECD, 2023). In practice, CT is often introduced before any formal programming occurs. Children first learn to reason through problems, test out ideas, and explain their thinking, the foundational skills that later

support more formal coding or digital interaction. Once a solution has been thought through, children may encode it into a sequence of actions, which can be carried out by a programmable device such as a robot (Lodi and Martini, 2021; Bers et al., 2022). This process is iterative: children tinker, test, and revise their strategies, a process Papert (1980) referred to as debugging.

This form of engagement not only supports cognitive development but also nurtures essential learning dispositions. The OECD (2023) highlights the social and emotional benefits of CT-based learning, including collaboration, communication, problem-solving, and persistence. These dispositions emerge as children actively engage in computational thinking practices, such as problem solving, sequencing steps, testing ideas, and refining solutions. Engagement in these hands-on play-based computational thinking experiences align closely with the goals outlined in national early childhood frameworks (NCCA, 2024; French and McKenna, 2022; CDECE, 2006), supporting the holistic development of the child. Within this context, CT in early childhood is best understood as what Bers (2010, p. 3) describes as "a type of analytical thinking," encompassing "a broad range of analytic and problem-solving skills, dispositions, habits, and approaches" (Pugnali, Sullivan and Bers, 2017, p. 172). These findings within the literature reinforce the definition adopted in this thesis, where CT is understood as a play-based form of analytical thinking encompassing a range of problem-solving skills, dispositions, and approaches, in which children engage with problem-solving by breaking them into smaller parts, recognising patterns, and constructing step-by-step solutions through hands-on, exploratory engagement.

A growing body of literature confirms that CT concepts can and should be adapted to the developmental stage of the child. Table 4 summarises several frameworks that support

this adaptation, each targeting different age groups with appropriately scaffolded concepts and tools.

**Table 4: Comparison of Early Childhood Computational Thinking Concept Frameworks**

| Researcher(s) | Age Range | Key CT Concepts | Pedagogical Focus |
|---|---|---|---|
| **Butler & Leahy (2020)** | 5 years+ | Algorithms<br>Abstraction,<br>Decomposition,<br>Generalisation<br>Debugging<br>Iteration | Learners construct tangible artefacts and share them. Emphasis on project-based and collaborative learning. |
| **Angeli et al. (2016)** | 5 years+ | Algorithms<br>Abstraction,<br>Decomposition,<br>Generalisation<br>Debugging | Concepts such as abstraction and generalisation suited to older primary age learners with more advanced reasoning. |
| **Glezou (2023)** | 4 years+ | 4-stage problem solving process:<br>1) Decomposition<br>2) Pattern Recognition<br>3) Abstraction<br>4) Algorithm Design | Focus on challenging children's thinking through play and experimentation, rather than tools.. |
| **Bers et al. (2022)** | 4 years+ | Algorithms<br>Iteration<br>Debugging<br>Modularity<br>Control Structures<br>Representation<br>Hardware/software | Seven powerful ideas from CT that are developmentally appropriate for young children. |
| **Bers, González-González, and Armas-Torres (2019)** | 3 years+ | Sequencing<br>Repeats<br>Conditionals<br>Debugging | Children as young as 3 years old could meaningfully engage with core computational thinking (CT) concepts.<br>Adapted curriculum integrating basic shapes, numbers, early literacy, and graphomotor skills. Conditionals were excluded. |
| **García-Valcárcel Muñoz-Repiso and Caballero-González (2019)** | 3 years+ | Basic Sequencing,<br>Action-instruction correspondence,<br>Debugging | Simplified and embodied CT experiences; The action-instruction element is the ability to relate the instructions to a robot with the action it performs |

The frameworks outlined in Table 4 demonstrate that while more advanced CT concepts (e.g., abstraction, generalisation, and modularity) may be more suited to children aged 5 and above, younger children can meaningfully engage with simplified and embodied CT experiences such as sequencing, debugging, and conditional logic through guided play

and physical interaction. The adaptations made by researchers such as Bers, González-González, and Armas-Torres (2019), and García-Valcárcel Muñoz-Repiso and Caballero-González (2019), provide strong evidence that CT can be both meaningful and accessible for children as young as three years old. Such adaptations typically involve reducing cognitive load, integrating familiar early learning content (e.g., shapes, numbers, motor skills), and using tactile, visual tools to support understanding. These developmentally appropriate approaches to CT, grounded in embodied learning, tangible tools, and age-specific frameworks, are closely aligned with the constructionist principles outlined by Papert and also reinforce the definition adopted in this thesis (Section 2.2.1). The following section reviews the current policy landscape related to CT, with particular attention to its place, or absence, within early childhood frameworks.

### *2.2.5 Education Policy Context*

As computational thinking (CT) gains prominence in educational theory and practice, policy becomes an important space where conceptual ideas translate into curriculum and pedagogy. While CT is increasingly visible in primary and post-primary education, its presence in early childhood education and care (ECEC) remains limited. This section situates the integration of CT within both national and international policy developments and highlights how this study contributes to ongoing efforts to define developmentally appropriate approaches for ECEC.

Computational thinking is still a relatively new area in the Irish education system. While it has appeared in policy and curricula at the primary and post-primary levels, it remains somewhat absent from national ECEC frameworks such as *Aistear: The Early Childhood Curriculum Framework* (NCCA, 2024) and *Síolta: The National Quality Framework for Early Childhood Education* (CDECE, 2006). Nevertheless, recent policy initiatives suggest a growing recognition of CT's importance, particularly in relation to STEM and

digital literacy. The Department of Education's *Digital Strategy for Schools to 2027* (DE, 2022) identifies CT as an emerging trend and commits to embedding coding and CT into the curriculum. The *Primary Mathematics Curriculum Draft Specification* (NCCA, 2022) also names CT explicitly, emphasising the importance of developing children's problem-solving and algorithmic reasoning skills. Similarly, the *Short Course Coding Specification for Junior Cycle* (NCCA, 2016) at post-primary level highlights CT and coding as tools for creativity and logic-based problem-solving. This progression is summarised in Table 5 showing the increasing policy support for CT, though notably, ECEC remains excluded from this trajectory.

**Table 5: Irish Education Policy that features Computational Thinking**

| Irish Education Policy that includes Computational Thinking | | | |
|---|---|---|---|
| **Year** | **Education area** | **Policy Document** | **CT Reference** |
| **2016** | Post Primary | Short Course Coding Specification for Junior Cycle. (NCCA) | Problem solving and computational thinking skills are developed in this course as students build and create software projects using their own ideas and imagination |
| **2016-2019** | Primary | Coding in Primary Schools initiative (NCCA) | Phase 1- to work with schools who could implement CT/ coding<br>Phase 2 collaborating with teachers who were not familiar with CT/ coding |
| **2017** | Post Primary | Leaving Certificate Computer Science curriculum | launched as a subject with CT elements (2018) |
| **2022** | Primary | Primary Mathematics Curriculum Draft specification for consultation<br>(NCCA) | Curriculum element 4: Applying and Problem Solving: Children should apply their mathematical knowledge and skills in flexible, efficient and creative ways to solve problems, conduct investigations and develop their computational thinking. |
| **2022** | Primary and Post Primary | Digital Strategy for Schools to 2027 (Department of Education) | Embedding computational thinking in the curriculum. An Emerging trend: Ongoing innovation in the area of coding and computational thinking at European level |

There is increasing recognition within Irish education policy that CT should build on children's prior learning, implying that ECEC plays a foundational role. For example, the Junior Cycle coding specification refers to the importance of "building on any coding

skills that primary students might have acquired" (NCCA, 2016, p. 4). Similarly, teachers involved in the Coding in Primary Schools Initiative suggested that children should be introduced to CT concepts as early as four years old, aligning with Junior Infant level. The *Primary Curriculum Framework* (NCCA, 2023) also acknowledges the valuable experiences that young children bring from ECEC, encouraging continuity in pedagogy and content across the transition to primary school. When these threads are woven together, they strongly support the argument that ECEC should begin to include CT experiences to provide a bridge between home, preschool, and primary learning (see Chapter 1, Section 1.2.4).

Internationally, CT is receiving significant attention in early education policy. The OECD's *Starting Strong VI: Empowering Young Children in the Digital Age* (OECD, 2023) calls on member countries to integrate computational thinking into national ECEC frameworks. CT is positioned as a core element of early digital literacy, fostering creativity, problem-solving, and technological understanding in children from an early age. This recommendation aligns with literature that frames CT and coding as a new form of literacy (Bers, 2018; Hall and McCormick, 2023), and as part of children's digital competence (Bers, González-González, and Armas–Torres, 2019). CT not only enables children to understand how technology works but also empowers them to become creators, not just users, of digital tools (Fridberg and Redfors, 2021; OECD, 2023). Despite this recognition, the OECD notes that only a small number of countries include CT in their early years curricula, and most existing research comes from short-term interventions rather than systemic implementation.

Several challenges remain for integrating CT into early childhood curricula. Educators often lack training, resources, or clarity on developmentally appropriate tools (Pugnali, Sullivan, and Bers, 2017; Zapata-Cáceres et al.,2021). In many countries, CT in ECEC

remains experimental rather than embedded (OECD, 2023). These gaps reinforce the need for practice-based, developmentally informed research that explores how CT can be meaningfully woven into play-based learning.

Irish early childhood education and care (ECEC) policy increasingly recognises the importance of STEM, problem-solving, and digital literacy, creating opportunities for CT integration. The Aistear literature review (French and McKenna, 2022) highlighted the growing significance of digital technologies and computational thinking (CT) related skills within children's everyday lives. The updated *Aistear: Early Childhood Curriculum Framework* (NCCA, 2024) strengthens this position by foregrounding STEM, science, technology, engineering, and mathematics, as key areas of early learning, and by encouraging children to explore scientific, technological, and mathematical ideas through play, inquiry, prediction, problem-solving, and analysis. Although *Aistear* does not explicitly reference digital literacy or CT, it recognises digital technologies as part of children's learning environments and emphasises active, playful, and enquiry-led engagement as foundational for children's emerging digital capabilities. The updated *Aistear* Guidelines (NCCA, 2024) further emphasise competencies such as creativity, communication, collaboration, and reasoning, skills that closely align with the cognitive dispositions underpinning CT. The *Literacy, Numeracy and Digital Literacy Strategy 2024–2033* (GoI, 2024) positions digital literacy as a core capability that begins in ECEC. While acknowledging that *Aistear* does not set specific expectations for digital literacy, the strategy notes that the framework provides meaningful opportunities for the integration of digital technologies through multimodal play, exploration, and inquiry. The Strategy highlights early thinking skills such as prediction, analysis, problem-solving, critical thinking, and reasoning, all of which overlap with CT concepts such as algorithmic thinking, pattern recognition, debugging, and decomposition. The accompanying Implementation Plan (GoI, 2024b) reinforces this direction by committing

to professional learning for educators in digital literacy, STEM, and inquiry-based pedagogy, positioning ECEC as a valuable stage in building children's confidence, creativity, and critical engagement with technology. Taken together, these policy developments create a favourable environment for integrating CT into Irish ECEC. Although CT has not yet been explicitly incorporated into national early childhood frameworks, the emphasis in *Aistear* and national digital literacy policy on inquiry, problem-solving, foundational thinking skills, STEM engagement, and meaningful use of digital tools provides a strong foundation for embedding CT through play-based, constructionist approaches.

This study aligns with current Irish and international policy directions that emphasise digital literacy, STEM education, and the development of foundational thinking skills in early childhood. By examining how computational thinking (CT) can be introduced through developmentally appropriate, play-based approaches in ECEC, the research directly addresses the gap highlighted by the OECD (2023): the absence of conceptual, empirical, and practical guidance on how CT should be implemented in early childhood settings. It contributes practice-based insights into how educators can meaningfully integrate CT using tangible tools and reflective pedagogy, supporting the evolution of national curriculum frameworks such as Aistear and emerging digital literacy strategies. In doing so, this study adds to a growing international body of work that positions CT not as a technical or specialised skill reserved for older learners, but as a core component of early learning in a digital world, relevant to all children. It also provides evidence that can inform Ireland's developing policy landscape by illustrating how CT can be embedded within play-based, child-centred practice, an area that policy acknowledges but has not yet operationalised in ECEC. To explore how CT can be realised in practice, the following section considers the role of programmable robotic kits (PRK) as developmentally appropriate, playful technologies that can mediate CT learning in ECEC.

## 2.3 Programmable Robotic Kits as Tools for Early Childhood Computational Thinking

Building on the conceptual and developmental foundations outlined in Section 2.2, this section examines the role of digital technologies, specifically programmable robotic kits (PRK), as tools for supporting computational thinking (CT) in early childhood education and care (ECEC). Although CT can be fostered through both unplugged and plugged approaches, PRK have emerged as particularly promising constructionist tools that enable young children to engage in programming through hands-on, playful, and tangible interaction. This section reviews the types of tools available, the rationale for using PRK in ECEC, and the growing body of evidence demonstrating their developmental and pedagogical value.

### *2.3.1. Digital Tools for CT: An Overview*

Although computational thinking (CT) is recognised as a form of thinking and problem solving, there is no guide or framework for selecting appropriate tools to support CT in early childhood education and care (ECEC) (OECD, 2023). This creates a challenge for educators who may already concerned and challenged with using digital technologies in ECEC and with young children's interest in it (French and McKenna, 2022; DES, 2020. Possible reasons for these challenges include educators concerns with children's overuse of screens, and dangers of the internet, as well as their own challenges with navigating technologies (DES, 2020; French and McKenna, 2022). Grieshaber et al. (2021) identify a gap between EC educators' digital literacy and young children's interest and experience in using digital technologies, while Johnston (2019) notes that young children often have "knowledge of technology that might be unfamiliar and even intimidating" (p. 306) for educators. What is known is that appropriate tools for supporting CT in early childhood should align with playful learning approaches that build on children's natural and innate

curiosity, and should encourage social play and collaboration (OECD, 2023; GoI, 2023; Bers, et al, 2014).

Currently tools for CT are broadly categorised as plugged or unplugged; either digital technologies such as digital devices, resources from computers, mobile devices, apps, games (Butler and Leahy, 2021) or non-screen, low technology (Bers et al., 2022). Examples of unplugged activities for CT ECEC can include sequencing a familiar story in a logical order or following a set of instructions to complete a hands-on task in a logical order. Unplugged tools provide a screen free way to encourage CT without a focus on using a coding or programming language (Bers et al., 2022). Using unplugged tools to encourage CT in ECEC has benefits in relation to the contested issues with screen time, concerns about the appropriateness of screen-based devices, passive screen use and the internet (Greishaber et al., 2020) and the recommendations to limit access to screens to less than an hour per day for children between 2-5 years old (WHO, 2019; OECD, 2023; UNICEF, 2022). However, some recent research findings suggest that unplugged tools may not be as effective in supporting young children's CT as plugged digital technologies (Pugnali, Sullivan, Bers, 2017). Possible factors include unplugged being more abstract and not so engaging as digital tools as generally young children are excited and drawn to digital technologies (Pugnali, Sullivan and Bers, 2017).

Plugged devices can include screen-based digital technologies that feature applications children can engage with, such as computers, tablets, mobile touch screen devices and non-screen technologies such as robotics kits (Sullivan, Bers and Mihm, 2017; Munoz-Repiso and Caballero-Gonzalez, 2019; OECD, 2023). Programmable robotic kits offer children a 'screen free' playful introduction to programming and computational thinking with opportunities to engage in a 'learn by doing' approach to analysis and problem solving, where "children are not afraid to make mistakes." (Bers et al., 2022, P.24). They

provide a tangible way for children to programme using the robot and props as physical objects, in the same way words and symbols on a computer screen would be used in graphical programming (Sullivan, Bers and Mihm, 2017). The haptic characteristics of robotic kits have benefits in that children get to directly interact and touch the robot ('object'), see and hear it respond through movements, which provides an additional sensory input for children (Kewalramani et al., 2023). Recent research identifies that young children have improved computational competence, digital literacy, problem solving and sequencing skills after programming with tangible robots (Munoz-Repiso and Caballero-Gonzalez, 2019), and also when compared with graphical programming (Pugnali, Sullivan and Bers, 2017). Recent research from Yang, Ng, Su (2023) illustrates that when using storytelling as a pedagogical approach, robotics programming has a more significant effect than tablet programming in terms of promoting children's computational thinking. Given this, PRK are increasingly recognised as developmentally appropriate digital tools that align with early childhood pedagogy and support CT through playful, hands-on engagement.

### *2.3.2 Why Programmable Robotic Kits? A Constructionist Rationale*

Building on the constructionist principles outlined in Section 2.2.3, programmable robotic kits (PRK) can be understood as particularly appropriate digital tools for supporting computational thinking (CT) in early childhood. Constructionism emphasises that young children learn most effectively when they can explore ideas through hands-on engagement, playful inquiry, and the manipulation of tangible materials (Papert, 1980; Bers, 2010). PRK naturally embody these qualities by facilitating children to create, test, and refine ideas through direct interaction with a physical robot (Bers et al., 2022). A key affordance of PRK is that they make abstract CT concepts visible and actionable (Bers, 2010). When children arrange coding tiles, press directional buttons, or tap instruction cards, and then observe how the robot responds, they receive immediate feedback that

supports their understanding of sequencing, cause-and-effect, and representational correspondence (Sullivan, Bers and Mihm, 2017). Such tangible systems help children link symbolic instructions with physical outcomes—an essential foundation of CT (Fridberg and Redfors, 2021; OECD, 2023). Tangible PRK also support representational fluency, the ability to understand how symbols correspond to actions (Pugnali, Sullivan and Bers, 2017). Studies identify that young children can develop a clear understanding of how instructions correspond to robot movements when those instructions take the form of physical tiles, cards, or blocks (Fridberg and Redfors, 2021; Sullivan et al., 2017). The visibility of the action–instruction relationship helps children build foundational algorithmic thinking: planning steps, anticipating outcomes, testing ideas, and revising their program where needed.

Research also indicates that use of tangible PRK lowers the cognitive complexity typically associated with programming by enabling children to physically manipulate coding inputs and observe real-time responses (Pugnali, Sullivan and Bers, 2017; Munoz-Repiso and Caballero-Gonzalez, 2019). This can also be supported through the constructionist concepts of body-syntonic learning, where children use their own bodily logic, such as gestures, stepping out routes, or physically turning their bodies, to reason about directionality and movement (Papert, 1980; Ackermann, 2003). This sensory–motor grounding provides a developmentally appropriate from concrete action to support complex CT.

Many PRK are intentionally designed according to the constructionist design principles of low floors, wide walls, and high ceilings (Papert, 1980; Resnick, 2017). These principles help explain why PRK can support diverse learners within ECEC:

- **Low floors**: Entry-level interactions, such as tapping a single instruction tile, placing a command block, or pressing a forward button, enables young children to participate without reading fluency or prior coding experience.
- **Wide walls**: Open-ended materials and modular programming options facilitate children to create stories, design their own routes, solve problems collaboratively, and integrate the robot into play-based scenarios (Bers, 2019).
- **High ceilings**: As children grow more confident, PRK support increasingly complex CT practices, including multi-step sequencing, pattern recognition, debugging, and algorithmic thinking and planning (Lavigne et al., 2019).

These design qualities closely match early childhood pedagogy, where children need accessible yet flexible tools that allow for exploration, creativity, and progression.

Finally, PRK support the playful, collaborative learning valued in early childhood education. They lend themselves to storytelling, imaginative contexts, and group problem-solving: features that allow CT to emerge naturally through guided play rather than formal instruction (Bers, 2019; French and McKenna, 2022). This aligns with Irish early childhood frameworks that emphasise inquiry, creativity, and child-led exploration (NCCA, 2024). Together, these qualities position PRK as developmentally appropriate, constructionist-aligned technologies that support young children in exploring CT concepts through meaningful, hands-on, and playful engagement.

### *2.3.2. Early Programming with Robotic Kits*

Robotics kits offer young children from the age of three with opportunities to engage in early coding and programming in a hands-on tangible way that can foster computational thinking (Pugnali, Sullivan and Bers, 2017; Bers et al., 2022; Bers, 2018; Munoz-Repiso and Caballero-Gonzalez, 2019; Romero-Tena and Romero-Gonzalez, 2020; Sullivan, Bers, Mihm, 2017; Murray, 2023). Some of the types of robotics kits used in recent research with young children include the *KIBO robotics construction kit* (Sullivan, Bers and Mihm, 2017; Bers, 2018), floor robots such as *Bee-bots* (Munoz-Repiso and Caballero-Gonzalez, 2019; Caballero-Gonzalez and Munoz-Repiso, 2021), Blue-*bots* (Fridberg and Redfors, 2021), *Turtle bots* (Nam, Kim, Lee, 2019), and *RoboTito* (Gerosa, Koleszar, Tejera, Gomez-Sena, Carboni, 2022).

Young children get to bring robots to life through the 'programmes'; the sequences of instructions they create with tangible blocks or directional cards (the code) that can be sequenced in multiple combinations that allows the robot to move and complete tasks (Bers, 2010). How the robots are programmed differs depending on the kit; KIBO involves a series of block and sensors that children use to construct their robot, whereas Bee-bots and Blu-bots require children to press the direction buttons on the floor bot to create a sequence of movements (Bers et al., 2022). The process of programming a robotic kit involves engaging with a range of computational thinking concepts; for example, algorithms, where the order or sequence of the commands matters, can be described as 'powerful ideas' (Pugnali, Sullivan and Bers, 2017). Underpinned by Papert's 'powerful ideas' for computer science, Sullivan, Bers and Mihm (2017) identified seven 'powerful ideas' (Table 6) of computational thinking: algorithms, modularity, control structures, representation, hardware/software, the design process, and debugging, that were included in the design of the *Kibo robotics construction kit* (Bers et al, 2022, p.11).

**Table 6: Seven Powerful Ideas for Early Childhood Computational Thinking - adapted from CT Concepts for KIBO Robotic Kits (Sullivan, Bers and Mihm, 2017, p.3)**

| ***Concept/ powerful idea*** | **Example when programming with robotic kits** |
|---|---|
| *Algorithms* | Children use the robot to explore logical organisation and sequencing using tangible programming blocks or direction buttons/ direction cards |
| *Modularity* | Children learn how to break up a large job into smaller steps when programming the robot to navigate mazes or complete challenges |
| *Control Structures* | Children explore the ways the robot can make decisions based on conditions using Repeat Loops and Conditional Statement blocks or direction cards/buttons. |
| *Representation* | Children learn that the colours and symbols on the blocks or direction cards/ buttons represent different types of actions |
| *Hardware and Software* | Children learn that computing systems, like KIBO, need both hardware (the robot or robotic parts) and software (the programming blocks, direction buttons) |
| *Design Process* | Children move through an iterative process used to develop programs and tangible artifacts |
| *Debugging* | Children troubleshoot their code when the robot does not behave as expected |

These seven 'powerful ideas' foster young children's computational thinking concepts (Sullivan, Bers and Mihm, 2017) and can provide a useful guide for selecting appropriate programmable robotics kits (PRK) as well as acting as a framework for planning and assessing young children's engagement with computational thinking.

### *2.3.4 Benefits of PRK for Young Children*

Programming PRK supports young children's holistic learning and aligns closely with Irish ECEC policy (NCCA, 2024; 2023; French and McKenna, 2022; GoI, 2023a; DE, 2023). Computational thinking supports young children's cognitive development in the areas of visual memory and ability to sequence, as well as executive function in the areas of inhibitory control, working memory and mental flexibility which contributes to self-regulation (Nam, Kim, Lee, 2019; Romero-Tena and Romero-Gonzalez, 2020; Bers et al., 2022). Programming robots also promote the use of scientific language (Fridberg and

Redfors, 2021) and overlap with inquiry processes such as asking questions, testing solutions, and iterating designs (Bers et al., 2022). Socially, robotics activities foster the Positive Technological Development (PTD) competencies: content creation, creativity, communication, collaboration, community building, and choices of conduct (Bers et al., 2014; Bers et al., 2022). In relation to literacy and language development, programming robotic kits provide opportunities for young children to engage in coding, which has parallels with acquiring a new language and developing literacy (Fridberg and Redfors, 2021; Bers, 2018, 2019; Bers et al., 2022). Wellbeing is another area that can be positively impacted through young children's digital play with PRK (Fridberg and Redfors, 2021; Bers, 2018; Kewalramani et al., 2021; Pugnali, Sullivan and Bers, 2017; Silvis et al., 2022; Yang et al., 2023). Young children have opportunities to engage in social play, and through this they develop prosocial behaviours as they collaborate in programming the robots with their peers, and sharing ideas, creating and solving problems together (Bers et al., 2022). Robotic kits have also been found to provoke a relational response and connection from young children that supports children's wellbeing, in a way that unplugged, or screen technologies don't (OECD, 2023, Silvis et al., 2022, French and McKenna, 2022). In recent research by Silvis et al. (2022), they noted that the young children developed caring relations with the robots, engaging in robot talk, thinking about the robot and talking to them, and this overflowed into their coding, which highlights a possible added value of introducing children to programmable robots at an early age.

### *2.3.5 Considerations and Limitations*

The OECD (2023) suggest that consideration also needs to be given to the fact that young children are in the stages of early literacy, not yet fluent readers and therefore robotics kits should be selected based on building on where 'children are at' in terms of fluency with number and directional symbols (forward, backwards, left, right). Another noted limitation of programming with robotic kits is that the pedagogical approaches for

computer science and computational thinking traditionally come from STEM disciplines, which is based on solving challenges with increasing complexity and as such tend to ignore the more "…expressiveness and communicative functions of programming" (Bers, 2019 p.503). Bers (2019) suggests viewing coding as a language and thus providing young children with opportunities to communicate and express their ideas in that language rather than being overly focused on solving puzzles. One other limitation to integrating the use of PRK in ECEC is educators' lack of confidence with digital technology can also shape decisions about using PRK (French and McKenna, 2022; DES, 2020; GoI, 2023a). Research points to educators' uncertainty about integrating technology into play-based pedagogy (Johnston et al., 2020; Edwards, 2013; Undheim, 2021). Conflicts between educators' digital beliefs and their play-based pedagogical orientations may also inhibit integration (Vidal-Hall et al., 2020; Palaiologou, 2016). The OECD (2023) emphasises that digital tools should enhance, not replace, existing curriculum priorities, and that more research is needed on how to enact CT in ECEC practice and appropriate CT pedagogies for ECEC.

### *2.3.6 Summary*

Programmable robotic kits offer a developmentally appropriate, constructionist-aligned, and engaging way for young children to develop computational thinking. Evidence shows that PRK support CT concepts such as algorithmic thinking, pattern recognition, and debugging while simultaneously contributing to broader cognitive, linguistic, social, and emotional development. However, the success of PRK depends not on the technology itself but on the pedagogical approach. Meaningful CT learning requires guided participation, intentional planning, and rich opportunities for playful exploration. Therefore, the next section examines purposeful play and pedagogy, the foundation through which PRK can support computational thinking in ECEC.

## 2.4 Purposeful Play and Pedagogies to Support Computational Thinking

As programmable robotic kits (PRK) offer new possibilities for supporting computational thinking (CT) in early childhood, it becomes essential to consider the pedagogical approaches that make this learning meaningful. Digital tools alone do not generate CT (Butler and Leahy, 2021); rather, CT emerges through the ways children play, explore, imagine, collaborate, and are supported by educators. Play, central to early learning and emphasised in Aistear (NCCA, 2024) provides the developmental and pedagogical grounding through which young children can meaningfully engage with computational ideas. Aistear (NCCA, 2024), suggests that young children should have opportunities to engage in the full spectrum of free-play, guided-play and educator-led playful experiences. Through this lens play in ECEC can be conceptualised as a continuum ranging from child-initiated free play through guided play to more structured, educator-led playful experiences, as previously discussed in Section 1.1, and shaped by shifting relationships between children's agency, educator intentionality, and curricular goals. Wood and Hedges (2016), suggest these relationships are not neutral but reflect wider tensions between freedom and control, process and content, and child-led versus policy-driven priorities in curriculum enactment. Within this continuum is free play, characterised by children's autonomy; it is self-directed and self-chosen, driven by intrinsic motivation, and open-ended exploration (Gray, 2009). Other guided and purposeful forms of play involve increasing levels of educator involvement, support and intentionality, while still maintaining the essential characteristics of play (French and McKenna, 2022). As illustrated in Figure 7, purposeful play, situated within this continuum of play, can be understood as an integrative pedagogical approach in which child-led activity is intentionally co-constructed and supported by educators to promote specific learning outcomes.

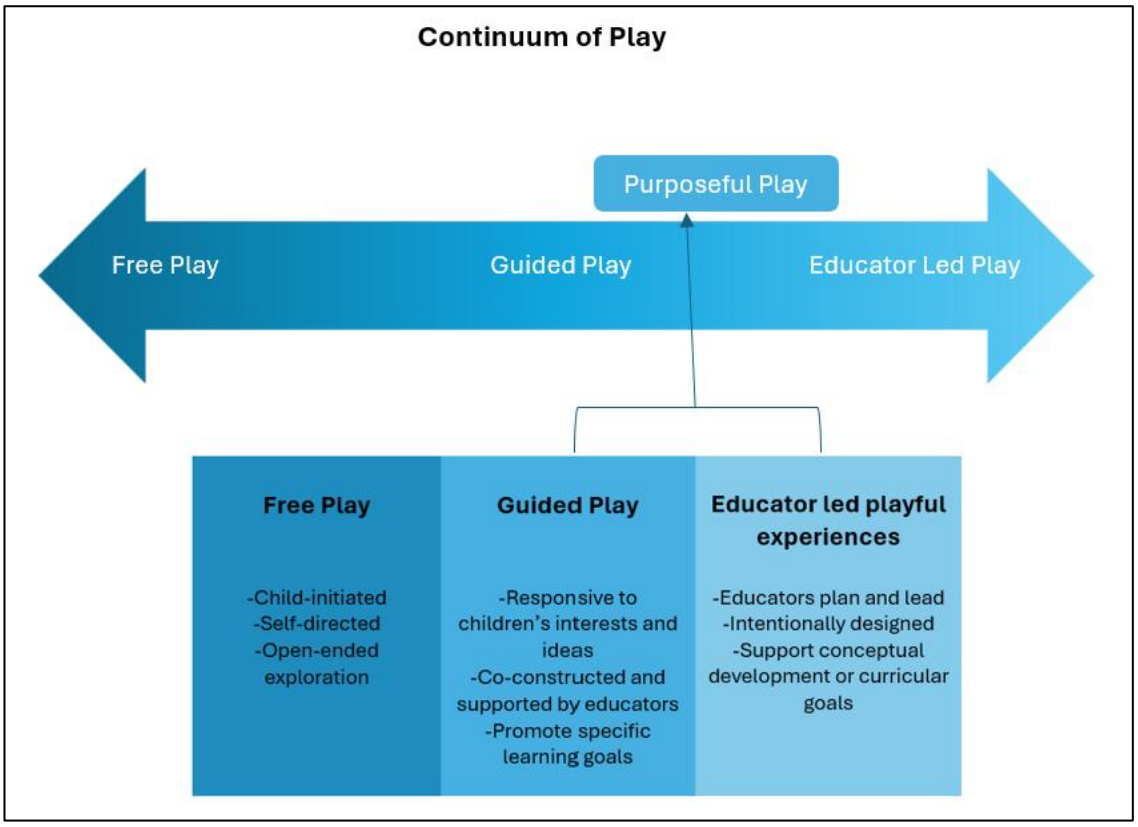



**Figure 7 Purposeful Play Positioned within the Continuum of Play**

This aligns with sociocultural perspectives on guided participation (Rogoff, 2003), where learning is co-constructed through shared activity, and with Fleer's (2011; 2021) conceptualisation of intentional pedagogy, in which educators deliberately structure play experiences to support conceptual development. It is also compatible with constructionist principles, where programmable robotic kits function as 'objects to think with' (Papert, 1980), enabling the children's thinking to become externalised and visible to educators in tangible ways. This creates opportunities for educators to respond intentionally, extending children's emerging CT concepts and ways of thinking. It also reflects Ackermann's (2003) ideas on pedagogical positioning where educators responsively move between stepping back to support exploration and stepping in to guide, extend, and deepen understanding at critical moments in the learning process. In the context of computational thinking, purposeful play provides an effective pedagogical approach, as it enables children to engage in hands-on, exploratory, and imaginative interaction with

programmable robotic kits, while being supported to develop problem-solving strategies, sequencing, and debugging skills in developmentally appropriate ways (Bers et al., 2022; OECD, 2023). This understanding also corresponds with Wood and Hedges' (2016) identification of a dual focus in play-based pedagogy, in which children's self-chosen play both informs curriculum design and is complemented by educators intentional introduction of content through pedagogically framed experiences. In this way, purposeful play can therefore be understood as a negotiated pedagogical space in which children, educators, and curricular intentions interact. In this space, curricula is co-constructed through what Wood and Hedges (2016) describe as "complicated conversations" (p. 398) among participants, practices, and forms of knowledge. This section examines how different forms of play, together with intentional and responsive pedagogies, enable CT learning with PRK, and how children's funds of knowledge, cultural tools, and educator-guided interactions shape these learning opportunities.

### *2.4.1 Why Play Supports CT in Early Childhood*

Internationally, there is growing recognition that playful learning provides a strong pedagogical fit for CT in early childhood (Bers et al., 2019, 2022; OECD, 2023). Bers' "playground approach" positions coding as imaginative, collaborative, and inquiry-led; qualities that resonate with Aistear's emphasis on play, exploration, and emergent curriculum (NCCA, 2024; French and McKenna, 2022). Play lends itself to CT because it is process-focused, exploratory, and motivated by children's intrinsic curiosity. During play, children engage in a distinctive motivation and mental attitude that integrates thinking, action, problem-solving and communication (Gray, 2009; Wood and Hall, 2011). During play, children engage deeply in problem-solving, take risks, test ideas, negotiate tensions, and return repeatedly to challenges (Galbraith, 2022; Colliver and Doel-Mackaway, 2021), all behaviours closely aligned with CT dispositions such as sequencing, debugging, prediction, and reasoning. Play's open-endedness allows children

to explore CT concepts in ways that feel meaningful to them, without the pressure of "getting it right" on the first attempt (Lavigne et al., 2019). Aistear (NCCA, 2024) strengthens this alignment by highlighting inquiry, prediction, logical thinking, analysis, and problem-solving as key elements of the Exploring and Thinking theme. Although CT is not explicitly named, its principles are visible throughout the framework, which positions play-based, hands-on learning as foundational for early digital capabilities. In this way, PRK and CT can be woven naturally into early childhood pedagogy rather than viewed as separate or technical domains.

### *2.4.2 Playful Exploration and Tinkering with PRK*

Playful exploration is central to early childhood learning and to the design of Ireland's emergent and inquiry-based curriculum (NCCA, 2015; 2024; French and McKenna, 2022). Opportunities for hands-on active play provides young children with freedom to focus on the process which is valuable in provoking their thinking and exploration (Nilsson et al., 2018). During playful exploration, children take on the role of explorer, scientist or investigator, engaging with the concrete materials in their environment (GoI, 2023a). With PRK, this means pressing buttons, experimenting with sequences, manipulating coding cards, predicting what might happen, and trying and adjusting their ideas. Through this process, children have opportunities to question, hypothesise, compare, predict, test, analyse, share discoveries and problem solve, core features of scientific thinking and reasoning (GoI, 2023a). Research highlights that CT is highly visible in children's "tinkering" experiences (Bers et al., 2022). Sullivan et al. (2017) demonstrate how preschool children engage in early algorithmic thinking and debugging when they tinker with robot commands, adjusting instructions when outcomes do not match expectations. Tinkering with PRK also creates opportunities to explore powerful ideas of CT such as modularity, abstraction and algorithmic logic. Children compare possible pathways, test sequences, and adjust step-by-step, building foundational

algorithmic logic in playful ways. Nilsson et al. (2018) suggest that both spontaneous child initiated playful explorations and meaningful child-educator projects can be beneficial in fostering young children's thinking. This understanding aligns with Wood and Hedges' (2016) identification of a dual focus in play-based pedagogy, where children's freely chosen play informs curriculum design, while educators intentionally introduce content through pedagogically framed play experiences. This duality is central to purposeful play, which must simultaneously remain responsive to children's ideas while enabling engagement with specific conceptual domains such as computational thinking. This dual emphasis reflects the balance described in Aistear (NCCA, 2024), where educators follow children's interests while also offering experiences that introduce new possibilities and extend thinking. Playful exploration with PRK therefore provides the foundation upon which educators can later introduce more intentional scaffolding, such as encouraging children to verbalise predictions, reflect on errors, or compare different strategies.

### *2.4.3 Imagination and Pretend Play as CT Resources*

Pretend play offers unique opportunities for children to represent ideas, think symbolically, and create hypothetical scenarios; processes that support deeper engagement with CT concepts such as sequencing, scenario planning, abstraction, and problem solving (Vogt and Hollenstein, 2021). Through the lens of Vygotsky's (1978) play theory, imagination should be considered an integral aspect of realistic thinking; that thinking is not possible without imagination (Nilsson et al., 2018; Fleer, 2021). Pretending provides a way for young children to engage in abstract thinking and conceptual development as they bring reality and their imagination together through 'as if' thinking (Colliver and Veraksa, 2021). Through pretend play children have the opportunity to explore ideas, hypotheses and scenarios in a way that is not possible in reality, and they do this by setting their own boundaries within the pretend play: for

example, a stick becomes a horse (Colliver and Veraksa, 2021; Nilsson, et al., 2018). Nilsson et al. (2018) suggest imagination and realistic thinking are both necessary components in play, with imagination providing a bridge between reality and abstract thinking when children play with objects. In the context where the object is a programmable robotic kit, creating an imaginary scenario where the robot is a character with a story and problem to be solved gives the children the opportunity to think with the robot character; the robot becomes a bridge between reality and what is possible. Grounding the scenario in the children's 'real world' experiences and interests supports them to make meaning and enables them to imagine 'as if' when solving the problem.

Benefits of providing pretend and imaginary play opportunities for young children include supporting the development of abstract thinking, concept formation, executive functioning and complex cognitive processes (Fleer, 2011; 2021; Colliver and Veraksa, 2021; Walker et al., 2020). Particular approaches identified include using imaginary play to build meaningful problems that children solve, designing the learning environment so young children can move between imaginary and real worlds as part of solving a problem based on a story; the educator takes a play role with the children and together all of the children enter into an imaginary physical Playworld space (Fleer, 2011; 2021). When adults participate in shared imaginary play, offering characters or challenges within the narrative, children are supported to "think in the concept" while remaining immersed in play. Stories provide a good starting point or framework for children to problem solve and engage in scientific thinking.

Story-based programming has been identified as a powerful way to introduce CT in developmentally appropriate ways (Yang et al., 2022). Embedding PRK within stories allows children to plan sequences as part of a meaningful narrative and supports richer reasoning as they consider the "story logic" of the robot's movements. This aligns with

Aistear's (NCCA, 2024) emphasis on storytelling, role-play and narrative imagination as key pathways for learning. Silvis et al. (2022) also found that young children were drawn to imaginative scenarios rather than solely focusing on the programming, and when there were opportunities for programmable robots to become characters, young children developed caring relations with the robots and engaged in robot talk. Relational aspects started to develop with the young children thinking about the robot and talking to them, which overflowed into their coding decisions; they made programming decisions and solved problems based on their own robot stories.

### *2.4.4 Intrinsic Motivation and Children's Digital Funds of Knowledge*

Intrinsic motivation is another key characteristic of young children's play that has potential to support their computational thinking (CT) through being a driver of their learning, thinking and interests. Young children's intrinsic motivation can be understood as their inner drive to be curious, question, seek answers, try things, take learning risks, and make decisions and choices on how they will direct their playful investigations and explorations; it shapes their play (Colliver and Doel-Mackaway, 2021; Gray, 2009). When children are self-directed and intrinsically engaged, they are more willing to persevere through challenges, revisit ideas, and debug errors, which are valuable CT behaviours. Young children's intrinsic motivation and play preferences are influenced by their previous experiences and understandings of their world and these existing ways of knowing or 'funds of knowledge', influence how they collaborate, explore and problem solve (Hedges et al., 2011; Chesworth, 2016; French and McKenna, 2022). It is therefore important that educators recognise and tune into these funds of knowledge and the working theories that develop from them (Hedges et al., 2011; Chesworth, 2016).

Drawing on sociocultural perspectives, children's funds of knowledge, everyday experiences as part of their lives at home, preschool and in their community (French and

McKenna, 2022), shape how they make meaning during play (Hedges, 2011; Hedges and Cooper, 2018; Chesworth, 2016). Children co-construct meaning through their play when they draw on these shared funds of knowledge (Chesworth, 2016). When young children have opportunities to "collaboratively construct and share funds of knowledge", they can start to develop working theories which Hill and Wood (2019) suggest can be "drivers of their learning" (p.1). French and McKenna (2022) note that young children's funds of knowledge can also come from their digital lives at home, and as such contribute to their increased motivation and interest in play with digital tools. This provides a good argument for welcoming and integrating digital technologies into planned play experiences within early childhood settings (Ralph, 2018; Danby et al, 2018; French and McKenna, 2022). In the context of supporting young children's CT, understanding and tuning into young children's funds of knowledge about their digital lives can help understand how they might shape or influence their inner drive for play with programmable robotic kits. In purposeful play with PRK, children's digital funds of knowledge become resources that support engagement, imagination, and problem-solving. They influence how children interpret the functions of a robot, how they verbalise their reasoning, and how they collaborate with peers to test ideas or debug problems. When educators build on these experiences, by inviting children to share what they know, narrate what they notice, or apply familiar strategies, they create more inclusive and meaningful opportunities for CT development (Yang et al., 2023).

### *2.4.5 Educators' Role: Guided Play, Guided Participation and Cultural Tools of Thought*

Supporting children's CT through PRK is not a matter of providing robots and leaving children to their own devices. Educators play a key role in shaping children's thinking through purposeful play, guided participation, and intentional but play-sensitive pedagogical strategies that ensure curriculum content can be embedded without

undermining the intrinsic nature of play. Wood and Hedges (2016) highlight that increasing emphasis on curriculum goals and outcomes can shift play towards more structured "educational play" (p.391), where adult intentions may dominate. This requires careful pedagogical judgement to maintain children's agency while also introducing meaningful content. Aistear (NCCA, 2024) positions the educator as agentic; an active, responsive participant in children's learning, someone who "notices-nurtures-responds-reflects" (p. 27) as part of shared activity. When educators adopt this intentional, relational stance, they create conditions in which children can explore computational ideas in playful, meaningful and developmentally appropriate ways. An important aspect of intentional pedagogy is the recognition that children's ideas and interests are the starting point for learning. When educators build on what is already meaningful to children, CT becomes more accessible. This reflects Aistear's (NCCA, 2024) emphasis on the educator responding to children's motivations and funds of knowledge and supporting them to extend their thinking through relational engagement.

From a sociocultural perspective, young children's learning is shaped through their participation in shared endeavours with more experienced others (Vygotsky, 1978; Rogoff, 2003). Rogoff's (1990) concept of guided participation is particularly relevant. Guided participation describes how children and adults work together in joint activity, where the adult supports children's thinking by structuring participation in subtle ways, offering hints, asking questions, building on children's inquiries and helping them make connections with prior experiences (Rogoff, 1990). In this approach, educators are neither directive instructors nor passive observers. Rather, they participate alongside children, making space for children's ideas while helping them to extend and deepen their thinking. In practice, guided participation often involves rich and extended dialogue, where educators draw children's attention to aspects of their play, or invite them to articulate what they think might happen next. It may involve joining children's imaginative play

with robots, modelling ways of thinking aloud, or gently prompting children to reflect on why something occurred which aligns with *Aistear's* (NCCA, 2009, p.31) strategies to encourage higher-order thinking.

These interactions also align closely with sustained shared thinking (Wood, 2007; Robertson et al., 2020), an approach that emphasises the co-construction of knowledge through meaningful conversation. As a concept sustained shared thinking "enables a context where educators can intentionally guide children's exploration and knowledge of the world" (Robertson et al., 2020, p. 378). It involves shared understandings between children and educator, where the educator takes the role of responding to and stimulating children's interests and inquiry, through "meaningful discussions that involve constructing meaning and understanding" (Wood, 2007, p. 313).

Guided play is another intentional pedagogy that supports CT in early childhood. Guided play maintains children's agency and playfulness while incorporating carefully planned opportunities for inquiry and problem-solving (French and McKenna, 2022; Sliogeris and Almeida, 2019). French and McKenna (2022) recognise that while children are curious and want to make sense of their world, "these skills do not persist without appropriate support, encouragement, and experiences that sustain children's interest and investigation" (p. 226). Within guided play, educators introduce questions or challenges or simply position themselves as co-players or co-learners so that children's ideas can be extended through shared exploration. This does not interrupt or direct the flow of play; rather, it sustains children's curiosity and supports them to engage more deeply with challenging concepts. Vogt and Hollenstein, (2021) and Kotsopoulos et al. (2022) highlight the value of guided pretend play in supporting young children to develop competences such as technical and digital skills, as well as creativity, communication, collaboration, critical thinking and problem solving. In the context of supporting young

children's CT through play with programmable robotic kits, a guided play approach was used to good effect by Hall and McCormick (2022) to explore the emergence of CT skills during guided play with a button-operated robots (Bee-Bots).

From a sociocultural viewpoint, PRK can also be understood as cultural tools of thought (Vygotsky, 1978; Rogoff, 2003). Cultural tools such as language, diagrams, maps and technologies support children to engage with symbolic systems and abstract ideas. PRK embody computational concepts such as sequencing, iteration and cause-and-effect, and their design encourages children to engage with these ideas through physical manipulation, prediction and feedback. When educators support children to think about why a robot moved in a particular way or what might happen if a step is changed, they help children connect the robot's behaviour to underlying principles. This dual scaffolding, from the technology and from the educator, makes CT concepts tangible and developmentally appropriate. When educators join children in imaginative play with robots, CT learning can be woven into the natural flow of play. This participatory stance also reflected *Aistear*'s (NCCA, 2024) emphasis on relationships as central to early learning, where knowledge is co-constructed and shared through joint engagement. Taken together, guided participation, sustained shared thinking, guided play and the use of cultural tools of thought illustrate the central role that educators play in supporting young children's CT. Through intentional involvement that respects children's agency and imagination, educators create the rich, relational and inquiry-focused environments in which PRK can function as meaningful tools for thinking.

### *2.4.6 Summary*

Purposeful play offers a powerful pedagogical bridge between CT concepts and programmable robotic kits in early childhood. Through exploratory play, tinkering, imaginative scenarios and shared problem solving and the use of digital funds of

knowledge, young children encounter and experiment with computational ideas in ways that are meaningful to them. Educators play a central role in designing these experiences and in guiding children's participation, using strategies such as sustained shared thinking, guided play, and scaffolding around cultural tools of thought. Taken together, these insights suggest that PRK are most effective for supporting CT when embedded within rich, relational, and play-based pedagogies rather than used as stand-alone technological tools. In this sense, purposeful play can be understood as an appropriate pedagogical approach that brings together children's agency, educator intentionality, and engagement with disciplinary knowledge, addressing the tensions between play, curriculum content, agency and control identified by Wood and Hedges (2016). The next section (2.5) builds on this by examining the professional knowledge, beliefs, and learning needs of early childhood educators as they design and facilitate CT experiences with PRK.

## *2.5 Educators' Professional Knowledge, Beliefs, and Professional Learning Needs*

This section examines the professional knowledge, beliefs and learning needs of early childhood educators in relation to integrating digital technologies, computational thinking (CT) and programmable robotic kits (PRK) in ECEC. Section 2.5.1 considers how professional knowledge in ECEC is conceptualised in the literature. Section 2.5.2 explores the barriers and enablers that shape educators' development of professional knowledge for using digital technologies, CT and PRK. Section 2.5.3 examines the features of professional learning needed to support educators in this area, including the potential of a learning ecology approach.

### *2.5.1 Professional Knowledge in ECEC*

Professional knowledge in ECEC has been conceptualised in the literature as a complex synthesis of theoretical understanding, practical expertise and ethical judgement. It involves not only 'knowing what' has been acquired through initial teacher education, but also 'knowing how', the tying together of everyday practice with theory within a specific social context (Campbell-Barr, 2018; 2019; Hordern, 2016). Campbell-Barr's (2017; 2018; 2019) conceptualisation of ECEC professional knowledge provides a useful starting point for understanding these complexities. Drawing on Aristotelian distinctions between *episteme* (Knowledge), *techne* (Skills) and *phronesis* (Practical wisdom), she argues that professional practice is shaped not only by educators' conceptual knowledge or skill but by their ability to integrate multiple forms of knowledge to act with intentionality and sensitivity in context. This can include theoretical knowledge ('knowing what'), educators capacity to apply knowledge in practice ('knowing how') and their ability to act with intentionality, values-awareness and contextual sensitivity ('knowing why'). Phronesis, or practical wisdom, represents the moment at which educators integrate theory, practical experience, and pedagogical values into context-specific decision making and action.

The *Competence Requirements in Early Childhood Education and Care* (CoRe) *report* (Urban et al., 2011) strengthens this view by emphasising that professional competence is relational, socially negotiated and collectively sustained. CoRe identifies the main knowledge, practice and values that contribute to educators' professional knowledge and positions professionalism not as an individual attribute but as a dynamic process emerging through interactions among educators, children and wider stakeholders. High-quality ECEC therefore includes relational practice informed by pedagogical values and collaborative engagement rather than solely on technical skills. This perspective is consistent with the considerations educators face when integrating digital technologies;

they need to ensure that digital tools complement children's learning and remain compatible with play-based pedagogy (Palaiologou, 2016).

Building on this, Campbell-Barr (2018, 2019), drawing on Bernstein's (1999) 'sociology of knowledge' framework, offers a useful lens for understanding how these different forms of knowledge come together in practice. She argues that professional knowledge in ECEC is created through the interplay of theoretical knowledge, experiential knowledge and educators' values and beliefs (Campbell-Barr, 2018; 2019). Professional knowledge emerges when educators draw on, reorganise and apply these varied forms of knowledge in ways that make sense within their specific context. Through this process of interpretation and recontextualisation, educators generate practice-specific knowledge that enables them to respond to children's learning needs. This perspective is particularly relevant to digital technologies and Computational thinking (CT), where educators require both content knowledge of CT concepts and pedagogical knowledge of how to support CT through developmentally appropriate, play-based strategies. This aligns with French and McKenna's (2022) observation that educators frequently feel underprepared in STEM and digital domains due to limited subject knowledge and uncertainty about appropriate pedagogical approaches.

Aistear (NCCA, 2024) sits within this broader literature by offering a curriculum framework that explicitly recognises educators as agentic professionals who interpret the curriculum through their knowledge, relationships and reflective capacities. Aistear (NCCA, 2024) positions educators' practice as informed by their understanding of each child and family, their professional experiences and their knowledge of the learning environment. The "agentic educator" (NCCA, 2024, p.18) is described as someone who uses professional judgement to interpret Aistear's Principles and Themes, make informed decisions, and design curriculum experiences that respond to children's needs, interests

and rights (NCCA, 2024). Agency in Aistear is expressed through responsive, relational pedagogy, educators engage in cycles of "noticing, nurturing, responding and reflecting" (NCCA, 2024, p.27), while also engaging in personal and peer reflection and building communities of practice that support shared learning. In encouraging broad and context-sensitive interpretations of the curriculum, Aistear reinforces an understanding of professional knowledge as interpretive, relational and situated. French and McKenna's (2022) analysis reinforce this by arguing that curriculum frameworks must acknowledge the realities of children's digital lives and provide scope for educators to interpret and integrate digital tools as meaningful cultural resources, rather than treating them as optional or peripheral. Taken together, Campbell-Barr's (2018; 2019) perspective on ECEC professional knowledge, the CoRe framework (Urban et al., 2011), Aistear's (NCCA, 2024) conception of the agentic educator and French and McKenna (2022) converge on a shared understanding of ECEC professionalism. Each position that educators draw on multiple forms of knowledge, conceptual, experiential, and value-based, to make informed decisions that are responsive to children and the setting context. This combined perspective aligns with DE (2023) (Section 1.3.2 p.) which emphasise the importance of educators knowing what, knowing how, knowing why, when supporting learning. It also highlights the breadth of knowledge required to integrate digital technologies and computational thinking in ways that are developmentally appropriate, relational, and consistent with play-based pedagogy.

### *2.5.2 Barriers and Enablers for Educator Knowledge Development*

A range of pedagogical, technological and contextual factors shape educators' capacity to develop the knowledge needed to integrate digital technologies such as programmable robotic kits and computational thinking skills into practice. Educators' pedagogical beliefs play a central role in shaping their engagement with digital tools. Vidal-Hall, Flewitt and Wyse (2020) and Palaiologou (2016) suggest that there is a conflict between

some educators' play-based pedagogical beliefs and their beliefs about young children's engagement with digital technologies, which shapes their decisions about integrating digital technologies into their practice. Grieshaber et al. (2021) argue that educators would benefit from professional learning opportunities that encourage them to understand that digital play is real play, and that digital technologies can be integrated rather than displace children's multimodal play.

There are also particular challenges for educators in using intentional pedagogies and integrating digital technologies into their play-based curricula. Intentional pedagogies involve purposeful pedagogical interactions to support the achievement of learning goals and can include approaches such as guided participation, sustained shared thinking, guided play (Grieshaber et al, 2021; French and McKenna, 2022). While these approaches can be powerful for supporting young children's conceptual understanding or higher order thinking, French and McKenna (2022) note, that for many educators these approaches "… can appear at odds with the familiar well-established play pedagogy…" (p. 229) that involve primarily observing and facilitating free play. Intentional and goal-orientated pedagogies require educators to "… be equipped with subject knowledge and skills that promote goal-orientated activity…" (French and McKenna, 2022, p. 229) and many require support to develop these practices.

A further barrier relates to educators' knowledge, skills and resulting confidence in relation to digital learning. Many educators report uncertainty about how to embed digital technologies within play-based pedagogy and limited familiarity with technological tools (EU Commission, 2015; DE, 2017; Undheim, 2021). The gap between children's digital fluency and educators' confidence is well documented, with research showing that children often possess greater ease, interest and experience with digital technologies than the adults working with them (Grieshaber et al., 2020). Johnston (2019) notes that

children may demonstrate technological knowledge that feels unfamiliar or intimidating to educators, which can influence their decisions about when or whether to integrate digital tools into practice.

These concerns are also evident within the emerging literature on educators' engagement with computational thinking and PRK. Studies by Papadakis et al. (2021; 2022), Glezou et al. (2020) highlight that while educators recognise the potential of PRK for supporting children's problem-solving, sequencing and early coding skills, they often feel they lack the content knowledge and pedagogical strategies necessary to introduce CT concepts confidently. Papadakis et al. (2021) found that educators frequently view robotics as valuable but technically complex, requiring support to understand both the tools themselves and the pedagogies that make CT accessible through play. Similarly, Glezou's (2020) work indicates that limited experience with robotics can lead educators to underestimate children's ability to engage with CT concepts, reinforcing hesitancy around implementation. This combination of limited subject knowledge, insufficient technological confidence and uncertainty about developmentally appropriate pedagogies constitutes a significant barrier to CT and PRK integration.

Change theories provide a valuable lens for understanding these interrelated barriers and the conditions that support educator engagement with and integration of digital technologies in their practice (Blackwell et al, 2013; 2014). Among available models, the *Unified Theory of Acceptance and Use of Technology* (UTAUT) (Venkatesh et al., 2003) (Figure 8) offer a relevant framework for considering how beliefs, knowledge, skills and contextual factors influence educators' decisions about adopting new digital tools or approaches

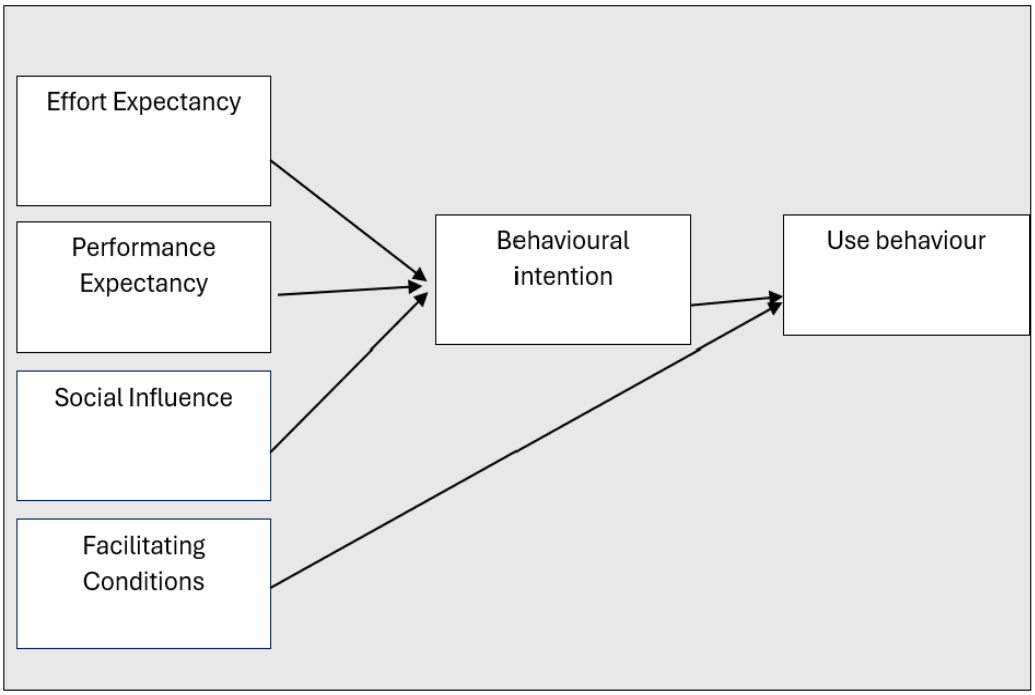



**Figure 8 UTUAT Model (Adapted from Venkatesh et al., 2003)**

UTAUT identifies four determinants (Table 7), *Performance Expectancy*, *Effort Expectancy*, *Social Influence* and *Facilitating Conditions*, that shape both intention and behaviour when interacting with new technologies, and have the potential to describe the motivating factors behind educator's decisions. When applied to ECEC, these constructs resonate strongly with the barriers discussed above. *Performance Expectancy* aligns with educators' beliefs about whether CT and PRK meaningfully support children's learning; *Effort Expectancy* captures concerns about the complexity or usability of PRK; and *Social Influence* reflects the impact of colleagues, leaders, families and wider societal expectations on decisions around children's technology use. Together, these constructs illuminate how educators' beliefs about play, digital technologies and children's capabilities intersect with their technological knowledge and confidence to influence practice.

**Table 7: Unified Theory of Acceptance and Use of Technology Constructs (adapted form Venkatesh et al., 2003)**

| UTUAT Constructs | Sub-determinants |
|---|---|
| **Performance Expectancy (PE)** | Perceived usefulness |
| | Extrinsic Motivation |
| | Job-Fit |
| | Relative Advantage |
| | Outcome Expectations |
| **Effort Expectancy (EE)** | Perceived ease of use |
| | Complexity |
| | Ease of Use |
| **Social Influence (SI)** | Subjective norm |
| | Social factors |
| | Image |
| **Facilitating Conditions (FC)** | Perceived behavioural control |
| | Facilitating conditions |
| | Compatibility |

Of particular significance in ECEC is the construct of *Facilitating Conditions* (Table 8), which refers to the organisational, material and relational supports that make it possible for educators to use a technology or approach effectively (Venkatesh et al., 2003). Facilitating conditions involves access to resources, support, and expertise, which are compatible with child centred play-based learning.

**Table 8: Facilitating Conditions sub-determinant (adapted from Venkatesh et al, 2003)**

| UTAUT Facilitating-Conditions (Venkatesh et al., 2003) | |
|---|---|
| **Facilitating Conditions:** | Availability of organisational, technical and pedagogical support and time. |
| **Perceived Behavioural Control:** | Confidence and resources to apply new learning. |
| **Compatibility:** | Fit with existing values and pedagogical approaches. |

In ECEC contexts, facilitating conditions include access to professional development, mentoring and supportive leadership, all of which shape educators' readiness to engage with digital technologies (Ifenthaler and Schweinbenz, 2013; Vaughan and Beers, 2017). These forms of support have been shown to increase educators' comfort with using technology and to strengthen the alignment between technological integration and their

child-centred, play-based values (Blackwell, 2014; Vaughan and Beers, 2017). Facilitating conditions also involve the availability of technology resources, including access to PRK digital tools, along with sufficient time to learn, practise and trial their use within the curriculum. Vaughan and Beers (2017) note that such opportunities are essential for educators to build confidence and competence, particularly when they are unfamiliar with digital tools. In addition, voluntary use of technology, where educators choose to engage with an innovation because it enhances learning rather than because it is mandated, supports more meaningful and sustained integration, as educators' perceived usefulness of PRK and CT increases when they experience these concepts as adding value to children's experiences (Vaughan and Beers, 2017). When these types of supports are in place, educators are better positioned to view digital play as compatible with multimodal, inquiry-based pedagogy, helping to overcome belief-based barriers that can otherwise inhibit the integration of digital technologies in ECEC (Palaiologou, 2016). Overall, UTAUT provides a useful lens for understanding how educators' beliefs, knowledge and contextual supports shape their decisions to engage with CT and PRK. In particular, its emphasis on facilitating conditions draws attention to the kinds of supports that enable educators to develop the knowledge and confidence needed to integrate digital and computational learning in early childhood settings. These insights align closely with the considerations that underpin effective models of professional learning, which the following section explores.

### *2.5.3 Professional Learning*

Professional learning is widely recognised as essential for sustaining high-quality early childhood education and care (ECEC). In European research and policy, it encompasses the formal, informal and non-formal opportunities through which educators build, update and consolidate their professional knowledge and competence over time (Peleman et al., 2017a). Evidence consistently shows that short, technical or decontextualised training has

limited impact on everyday practice, as it tends to focus on procedural skills rather than on the complex socio-pedagogical competences required in ECEC (Peleman et al., 2017a; Vandenbroeck et al., 2013). In contrast, longer-term, practice-embedded professional learning is associated with more meaningful and sustainable change because it supports educators to integrate new knowledge within the realities of their own settings (Peleman et al., 2017b).

Research further highlights the value of professional learning that promotes reflection, dialogue and collaborative inquiry. Bove et al. (2018) emphasise that professional learning is most effective when it enables educators to engage critically with colleagues, supervisors and families, and to interpret theory in relation to their own pedagogical context. Opportunities for reflection before, during and after professional learning help educators to connect new ideas to existing beliefs, values and experiences (Peeters et al., 2017a). Campbell-Barr (2018; 2019) similarly argues that professional learning must support educators not only to understand theoretical concepts but to develop practical, situated 'know-how' for working with young children. International evidence indicates that when professional learning encourages application, exploration and the active linking of theory and practice, it is more likely to contribute to rich learning environments and high-quality pedagogy (Peleman et al., 2017b). Such approaches acknowledge educators' experiential knowledge and position them as active constructors of knowledge rather than passive recipients of information (Osgood, 2010).

These principles are particularly relevant when professional learning focuses on computational thinking (CT), digital technologies and programmable robotic kits (PRK). As outlined in Section 2.2, educators often recognise the potential of PRK to support young children's problem-solving and sequencing, yet report feeling underprepared to integrate such tools into play-based curricula (Papadakis et al., 2021; 2022; Glezou et al.,

2020). Reported challenges include limited technological knowledge, concerns about developmental appropriateness and uncertainty about how to design play-based experiences that meaningfully support CT. Professional learning that responds to these needs must therefore be hands-on, contextually grounded and oriented towards inquiry (Stevenson et al., 2019). Studies of STEM and digital learning show that educators benefit from opportunities to explore digital tools, construct artefacts, collaborate with colleagues and engage in learning-by-doing (Stevenson et al., 2019; Vidal-Hall, Flewitt and Wyse, 2020). Papadakis et al. (2021) found that professional learning which allows educators to engage with robotics kits, experiment with coding tasks and iteratively test and refine their understanding significantly improves confidence, competence and willingness to implement CT activities.

Co-learning with children also emerges as an important feature of effective professional learning for CT and PRK. When educators position themselves as co-learners rather than as sole experts, the perceived gap between children's digital fluency and educators' confidence begins to narrow (Johnston, 2019). She notes that learning alongside children challenges the assumption that educators must hold expert knowledge in all domains in advance; instead, competence develops through shared exploration, multimodal problem-solving and following children's interests. Papadakis et al. (2021) similarly show that when educators participate in CT activities as learners or co-learners, they develop a more nuanced understanding of children's capabilities and are better able to design pedagogically meaningful robotics experiences.

The concept of learning ecologies provides a useful framework for understanding and designing the kinds of professional learning that can support educators to develop the knowledge, skills and dispositions needed to design learning experiences that develop young children's CT through purposeful play with PRK. Grounded in ecological theories

of development and sociocultural theories of learning (Bronfenbrenner, 1979; Rogoff, 2003), learning ecologies conceptualise learning as emerging from dynamic, interdependent relationships between people, activities, tools, values and contexts (Barron, 2004; 2006). Barron (2004) describes a learning ecology as the set of formal, informal and non-formal contexts and relationships that provide opportunities for learning through participation in activities involving materials, tools and other people. From this perspective, learning is distributed across settings and mediated by both technological and social resources. Formal learning contexts, such as courses or workshops, may introduce conceptual knowledge, while informal contexts, such as experimentation in one's own practice, afford rich and situated opportunities to build fluency through active engagement and iteration (Barron, 2006).

A learning ecology perspective is particularly relevant for professional learning focused on CT and PRK because it foregrounds the diverse conditions through which educators learn. Hands-on engagement with digital tools, practice-based inquiry in educators' own settings, co-learning with children, reflective dialogue with peers and support from mentors or experts all appear in the literature as features of effective digital professional learning in ECEC (Stevenson et al., 2019; Johnston, 2019; Johnston et al., 2020; Barron, Kennedy Martin and Roberts, 2007). Professional learning that provides educators with opportunities to work directly with PRK can increase confidence, enthusiasm and understanding of how technologies can function as pedagogical resources, particularly when this learning is embedded in their everyday curriculum and interactions (Stevenson et al., 2019; Vidal-Hall, Flewitt and Wyse, 2020). Practice-based inquiry allows educators to trial and adapt CT and PRK activities within their own contexts, observe how children respond and refine their approaches over time (Johnston et al., 2020).

Co-learning alongside children further enriches educators' learning ecologies. When educators and children co-construct and co-create as part of digital play, children's digital

funds of knowledge and interests can function as “islands of expertise” (Barron, 2006, p. 198), supporting educators to develop practical “know-how” for integrating digital tools into play-based learning (Lowrie and Larkin, 2020). Reflective dialogue with peers and mentors supports educators to analyse these experiences, make sense of challenges and embed new understandings into their practice (Barron, Kennedy Martin and Roberts, 2007; Romeu-Fontanillas et al., 2020). Engagement with specialists, mentors or more experienced colleagues can provide additional guidance and “bridging social capital” (Van den Beemt and Diepstraten, 2016, p. 167), helping to overcome hesitancy and legitimise the use of CT and PRK within early childhood curricula (Stevenson et al., 2019).

Taken together, these elements, hands-on engagement, practice-based inquiry, co-learning, reflection and mentor support, illustrate how a learning ecology approach offers a coherent framework for professional learning in this context. It recognises that educator learning is distributed across multiple settings, relationships and experiences, and that sustained, situated and relational learning environments are necessary for developing the confidence and competence to integrate CT and PRK meaningfully into play-based early childhood practice. This perspective aligns with the emphasis on facilitating conditions in UTAUT (Venkatesh et al., 2003), particularly the need for access to resources, time, support and aligned pedagogical values, and it provides a strong conceptual foundation for designing professional learning that responds to educators’ professional knowledge needs in relation to digital learning and computational thinking.

## 2.6 Conceptual Framework

The conceptual framework for this study (Figure 9) brings together the key ideas presented throughout Chapter 2 to explain how young children can engage in computational thinking through purposeful play with programmable robotic kits, and how

educators can be supported to design and facilitate such learning. It provides a contextual and visual representation of how the study's ideas, processes, and outcomes are connected (Berman, 2013). In doing so, it translates theoretical assumptions into a practical model for inquiry, guiding the design, implementation, and interpretation of the study (Grant and Osanloo, 2014). The conceptual framework builds directly on the Design-Based Research (DBR) process introduced in Section 1.4.1 (p. 31), embedding its iterative phases within the study's theoretical perspectives (Figure 5) and the broader Irish ECEC context. Together, they illustrate how theory and practice were connected through cycles of collaborative design, enactment, observation, reflection, and refinement (Philippakos et al., 2021). The framework integrates Constructionism (Papert, 1980, 2000, 2005), Sociocultural Learning Theory (Rogoff, 1990, 2003), and ECEC Professional Knowledge Perspective (Campbell-Barr, 2017, 2018, 2019) within the iterative structure of Design-Based Research (DBR). At its centre lies the co-design of purposeful play with PRK, representing the collaborative partnership between educators and myself as researcher. Through cycles of planning, enactment, observation, reflection, and redesign, theoretical ideas are enacted, tested, and refined in practice. Together, these perspectives support a qualitative methodology that examines both observable practice and the pedagogical thinking behind it which will be discussed in Chapter 3. Visually, the conceptual framework illustrates reciprocal learning relationships within the DBR process (Papavlasopoulou et al., 2019). The left-hand circles represent the educator's and my researcher-mentor professional knowledge, skills, and values feeding into the co-design of purposeful play with PRK (Campbell-Barr, 2017, 2018, 2019). The right-hand circles show the outcomes emerging from this collaboration: the children's development of CT and educators' understanding of CT and how to support children's CT development (Papert, 1980, 2000, 2005).

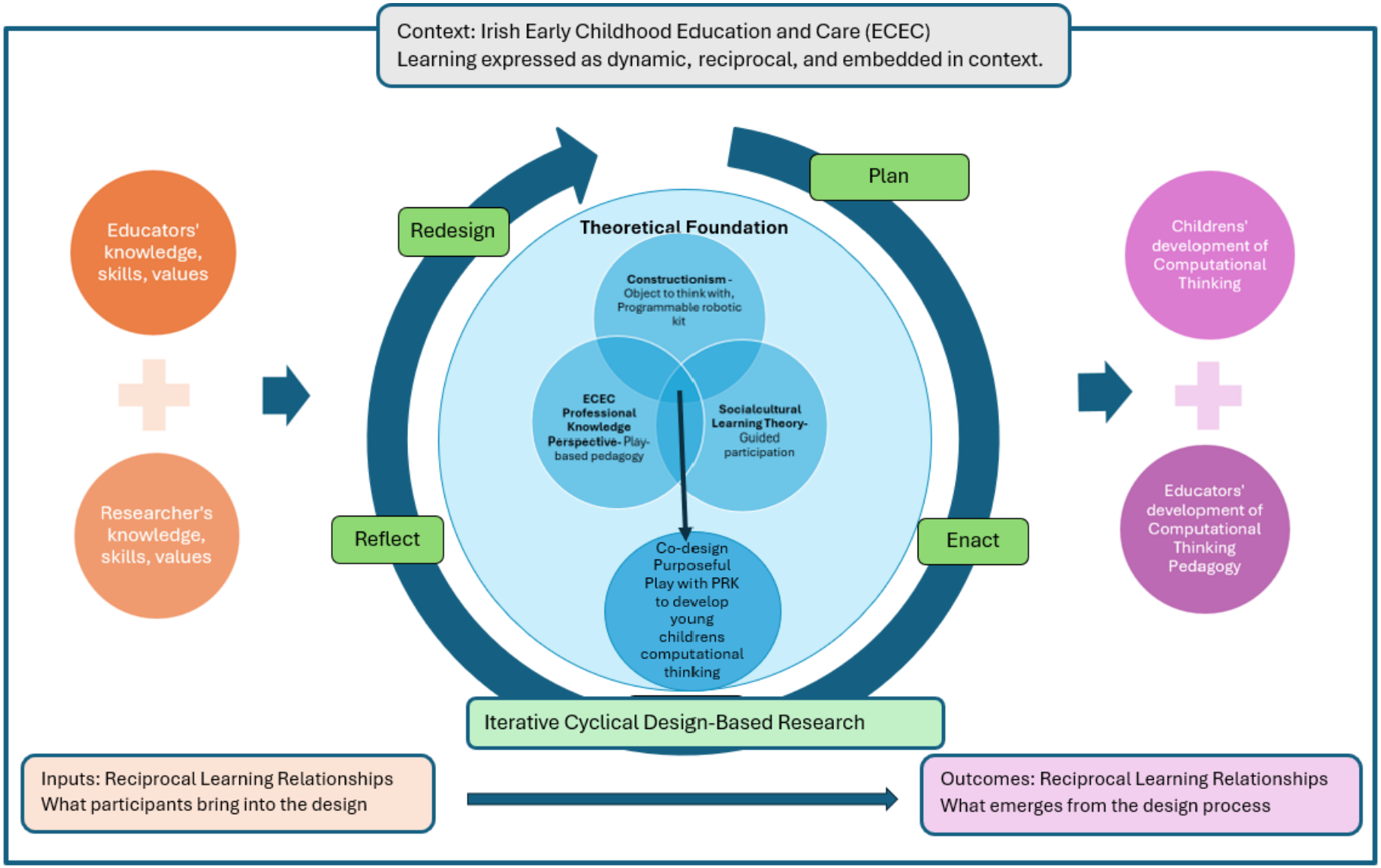



**Figure 9 Conceptual Framework for the study**

The co-design process, situated within overlapping theoretical perspectives and iterative DBR cycles, symbolises the interactive and reflective nature of learning, including collaborative dialogue and guided participation that occur during the co-design and reflection process (Rogoff, 1990, 2003). The circular configuration reflects the iterative and relational nature of DBR, in which learning is co-constructed through cycles of planning, enactment, reflection, and redesign (Papavlasopoulou et al., 2019). The outer contextual frame positions the study within the Irish ECEC landscape, acknowledging the influence of national policy, curriculum (NCCA, 2024), digital learning strategies presented in Chapter 1 and Chapter 2. This conceptual framework serves as an organising tool and analytical lens, ensuring coherence between the research aims, theoretical foundations, and methodological design (Grant and Osanloo, 2014). Ultimately, the framework demonstrates how theory and practice interact reciprocally in early childhood contexts, leading to the development of both professional and pedagogical knowledge.

## 2.7 Summary

The literature reviewed in this chapter establishes several key understandings about young children's engagement with computational thinking (CT) and digital technologies in early childhood education and care. Research highlights that children are capable of engaging with foundational CT ideas, such as algorithmic thinking, debugging and pattern recognition, when these are embedded in meaningful, playful contexts (Bers et al., 2022). Programmable robotic kits (PRK) emerge as valuable tools because they support hands-on exploration, co-construction, and multimodal expression. The literature also identifies intentional play pedagogies, including guided participation and sustained shared thinking, as essential for making CT developmentally appropriate. In parallel, scholarship on ECEC professional knowledge highlights that educators' pedagogical beliefs and technological confidence influence how CT and PRK, as digital tools, are integrated into practice. Effective professional learning must therefore be situated, reflective, collaborative and practice-based.

However, significant gaps remain, while CT and PRK research with young children is growing, far less is known about how educators learn to design and implement CT-rich learning experiences. Existing studies rarely examined educators' professional knowledge development in depth, particularly within play-based curricula (OECD, 2023). Within this context there is limited evidence on how educators interpret CT concepts, how they make pedagogical decisions during digital play, or how they negotiate tensions between play-based values and unfamiliar technologies. Few studies explore the co-design of CT activities with educators, and even fewer investigate iterative, collaborative approaches to professional learning, such as design-based research (DBR), that position educators as active collaborators. There is limited research situating CT pedagogy within the Irish ECEC context, where the national curriculum framework emphasises relational practice, agency, children's rights, and play-based learning (NCCA, 2024).

Overall, Chapter 2 demonstrates the need for research that examines how educators develop CT pedagogical knowledge through collaborative, practice-embedded professional learning; how they interpret CT within Aistear's (NCCA, 2024) play-based framework; and how PRK can be meaningfully integrated through purposeful play. The conceptual framework developed in this chapter, grounded in constructionism, sociocultural learning theory, and ECEC professional knowledge perspective, and enacted through DBR, provides the foundation for addressing these gaps. It guides the methodological design presented in Chapter 3, where the study investigates how co-design cycles can support educators' to design CT learning experiences and children's CT development in ECEC settings.

# Chapter 3: Methodology

This chapter outlines the methodological framework for a qualitative, interpretivist study that investigates how early childhood educators co-design and enact purposeful play experiences to foster young children's computational thinking (CT) using programmable robotics kits (PRK) in an Irish ECEC setting. Building upon the conceptual framework (Section 2.6 p. 91), which integrates constructionist (Papert, 1980), sociocultural (Rogoff, 1990), and professional knowledge perspectives (Campbell-Barr, 2019), the chapter first positions my role as a researcher-mentor, highlighting the relational, participatory nature of the inquiry. Then Design-Based Research (DBR) is introduced as the overarching approach, combined with an in-depth case study design to capture educators' experiences and meaning-making within their ECEC practice context (Cohen et al., 2018). The study is guided by the overarching research question:

*What are the facilitating conditions that support early childhood educators to design learning experiences that develop young children's computational thinking through purposeful play with programmable robotics kits in an Irish ECEC context?*

This research question and related sub-questions (Section 1.5.1 p. 34) collectively explore the conditions that support educators to design computational thinking focused learning experiences with programmable robotic kits. The questions examine how the co-design intervention and its features shape educators' knowledge and practice, and how their evolving ECEC beliefs inform the design of purposeful play. The chapter describes the four DBR stages (preparation, design, enactment and development of design principles), the six-week co-design intervention, and the multimethod data collection strategy (interviews, planning and debrief meetings, structured child observations and field notes), before outlining the reflexive thematic analysis and the ethical considerations related to assent, participation rights, power relations and data protection.

## 3.1 Researcher Positionality

Research philosophy serves as a roadmap' for inquiry (Sefotho, 2015), shaping how I understand reality, how I believe knowledge is generated, and how I position myself in relation to participants. In this study, my positionality is grounded in my professional background as an early childhood educator and lecturer and is closely aligned with the integrated theoretical perspective outlined in Chapters 1 and 2: constructionism, sociocultural learning theory and the ECEC professional knowledge perspective.

This study is situated within an interpretivist paradigm and underpinned by a social constructionist epistemology. Rather than treating computational thinking learning experiences as a pre-determined model of CT pedagogy, I view them as something that is co-constructed by educators, children, and myself as researcher-mentor within the ECEC research setting. My positionality is therefore both relational and participatory, I am not an observer, but an active collaborator whose presence shapes, and is shaped by, the inquiry process. In this sense, my positionality is best described as that of a researcher-mentor, bringing theoretical and practice expertise. I also shared the educators' starting position of uncertainty regarding how CT could be integrated into play-based pedagogy. My dual identity, partial insider to ECEC, partial outsider to the setting, shaped the design of the DBR cycles and required ongoing reflexivity about power, influence and interpretation throughout the study. This study adopts a relativist, relational ontology (Guba and Lincoln, 1994; Crotty, 1998) in which reality is understood as multiple, context-dependent, and continuously shaped through interaction (Scotland, 2010). In this inquiry, the 'reality' of CT in early childhood practice depends on the relationships, routines, tools and the constraints of the particular setting. Consequently, reality is understood in terms of how the educators, children and I make sense of and engage with CT during the co-design intervention. Epistemologically, the study is grounded in social constructionism (Crotty, 1998). From this perspective, meaning is constructed as people engage with and interpret the world. This

underpins the co-design nature of the research: rather than assuming the position of the sole expert, I worked with the educators to co-construct understandings of CT pedagogy through dialogue, shared activity, and reflection, consistent with the constructionist (Papert, 1980) and sociocultural perspectives (Rogoff, 1990) discussed in Chapter 2. Axiologically, I recognise that the study is value laden. My interpretation of CT in ECEC is shaped by underpinning beliefs on children's rights, wellbeing and agency, and play-based, relational pedagogy, as well as the educators' professional judgement. These values influenced the design, the focus of data collection and the way findings are framed and align with ECEC professional knowledge perspective (Campbell-Barr, 2019). In summary, my research positionality is interpretivist, constructionist, sociocultural and value oriented. This positionality provides the philosophical and practical foundation for the methodological choices outlined in the remainder of this chapter.

## 3.2 Research Approach: Design-Based Research (DBR)

Considering my positionality, Design-Based Research (DBR) provided the overarching methodological framework for this study. Campanella and Penuel (2021) note that DBR is particularly suited to educational settings where new goals are being identified and pursued that are not yet reflected in current practice. This was directly relevant here; the study introduced new practices related to CT and purposeful play with PRK and addressed the "how" sub-questions concerned with developing or shaping knowledge, design practices and beliefs. DBR was particularly appropriate given the aims and context of this study. First, it enabled me to take on the dual role of researcher and participant within the educational setting, seeking to understand a particular phenomenon, educators' development of CT pedagogy, while actively working to change practice (Bakker, 2018). Other interventionist approaches were considered and found to be less suitable, for example, an action research design would typically position the educators themselves as the primary researchers, which did not align with my role as an external researcher-mentor. The closed, controlled nature of

a Quasi/experimental intervention would have been incompatible with the play-based, relational nature of the ECEC context.

DBR involves the iterative design, implementation, and refinement of interventions in real-world educational settings, with the aim of improving practice while developing situated theoretical insights (McKenney and Reeves, 2012; Bakker, 2018). It is characterised by close collaboration between researchers and educators and by repeated cycles of design, enactment, and evaluation. Reeves (2006) presents DBR (Figure 10) as four connected phases; analysis of practical problems, development of solutions, iterative design cycles to test and refine and reflection leading to the development of design principles.

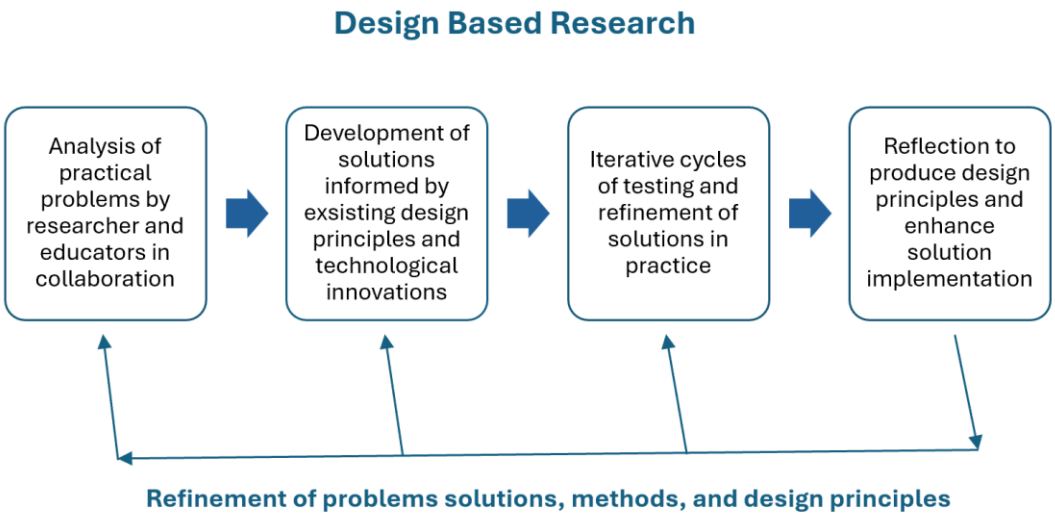



**Figure 10: Design Based Research (Based on Reeves, 2006)**

Bakker (2018) suggests that DBR sits between methodology (the study of methods) and method (a systematic way of doing things) and can be viewed as an approach, in a similar way to action research. While Phillips (2006) describes it as a methodological framework that incorporates a set of approaches. In this research context, DBR provided the methodological framework for implementing a pedagogical intervention with educators to

co-design purposeful play experiences that fostered computational thinking using programmable robotics kits (PRK).

The research met three key principles of DBR as identified by Bakker (2018). First, it was interventionist in nature; in collaboration with the educators, changes were made to their practice as part of the co-design process, and in doing so, I gained understanding of how to support the educators to co-design. As Bakker notes, if you want to change something you have to understand it, and if you want to understand something you have to change it; in this study, these two aims were intertwined. Second, the research involved both prospective and reflective elements: the prospective aspect involved planning and implementing the six-week intervention, while the reflective aspect involved analysing the co-design cycles of planning, play, and debriefing with the educators and the children, adjusting as needed. Third, the purpose of the research was both theoretical and practical. It sought to develop theory about how to support educators to design learning experiences that develop young children's CT through purposeful play with PRK in an Irish ECEC context, while simultaneously generating practically useful outcomes. The analysis identified facilitating conditions that supported the educators during the co-design intervention and used these insights to inform the development of a professional learning model. Within this qualitative DBR approach, learning was viewed as dynamic and relational, evolving through the interplay of theory, practice, and reflection during the six-week co-design intervention. The DBR cycles enabled an inquiry process between the educators and me that was participatory, contextually grounded, and responsive to emerging insights, consistent with the constructionist and sociocultural principles underpinning the study.

## 3.3 Case Study Design and Context

The focus on exploring the educators' participation in the co-design process guided the choice of exploratory case study methodology and the qualitative multi-method data collection and analysis methods. Yin (2013) defines a case study as "an in-depth inquiry into a specific and complex phenomenon (the 'case'), set within its real-world context" (p. 321). Similarly, Merriam (2009) conceptualises case study as an in-depth description and analysis of a bounded system. In this research, the 'case' or the bounded system is the intervention implemented within an early childhood education and care (ECEC) setting. An exploratory case study refers to a type of case study used when the research topic is still unclear, underdeveloped, or not yet well understood, and where the goal is to explore a phenomenon (in this study, the intervention) in order to generate insights (Yin, 2018). This research is designed as an exploratory case study situated within one early childhood setting, using multiple methods of qualitative data collection.

Merriam (2009) suggest that a case study methodology is particularly suitable for educational research as it enables in-depth investigation of complex social units consisting of multiple variables found in educational settings. A case study approach has potential to provide a rich holistic account of the phenomenon being studied and for advancing the knowledge base and bringing understanding of practice, problems and processes which can also be useful for informing policy and for studying innovation (Merriam, 2009). A case study approach supports a multi-method approach for exploring multiple sources of information and using diverse methods of data generation which can lead to rich description and in-depth detail that would not be possible if using only a single data set (Yin, 2018; Merriam, 2009). In this study, the qualitative multi-method design and case study focus were closely aligned with the DBR cycles with each stage of the intervention examined through the detailed, contextual lens of the case. In this way, the case study provided the overarching methodology for exploring practice within one ECEC setting, while the DBR cycles

provided a structure for cumulative and iterative learning through design, enactment, observation, reflection, and redesign.

In this study, the case comprised one early childhood education and care (ECEC) setting in Ireland and involved working closely with two early childhood educators and the group of eleven children in their care. The setting's practice was based on play-based curriculum consistent with Irish ECEC policy and practice, and the study was integrated into the educators' ongoing work rather than operating as a separate, add-on project.

### *3.3.1 The Research Setting*

The research took place in a community-based ECEC setting located in Dublin. The setting catered for children aged approximately 2- 5 years old and followed a play-based, emergent curriculum in line with the national curriculum framework, Aistear (NCCA, 2024). Daily routines typically included extended periods of free play, small-group activities, outdoor play, and whole-group gatherings. The intervention was woven into these existing routines rather than replacing them. Play-sessions with programmable robotics kits (PRK) were scheduled within the normal daily routine between 9:30 and 10:30am. This situated the research within the everyday learning environment and practice within the setting, consistent with the interpretivist and sociocultural underpinnings of the study.

The research setting was selected using a purposive sampling approach, in which cases are deliberately chosen for their relevance and ability to provide rich information for the study (Cohen et al., 2018), based on its accessibility and its relevance to the aims of the study. The setting was part of my professional network and the early childhood setting manager had expressed explicit interest in participating in the research. More, importantly, the setting was particularly suitable given its strong interest in early childhood STEM and digital literacy. Although selecting a familiar setting may introduce potential bias or validity issues, this was addressed through ongoing reflexive practice, peer debriefing and member checks

(see Section 3.8). This prior connection also facilitated access, supported the development of trust, and enabled a collaborative, co-design approach with educators.

### *3.3.2 Educator Participants*

Two early childhood educators, Elaine and Leah, participated in the study. They were selected because they worked with children within the appropriate age range, unlike other classes with a greater proportion of children under three years old, and both volunteered to participate when approached by the setting manager. Both were qualified early childhood educators with differing levels of education and years' experience working with young children (Table 9).

**Table 9: Educator Participant ECEC Experience and Qualifications**

| Educator | ECEC qualification- National Framework of Qualifications (NFQ) | Experience employed in ECEC |
|---|---|---|
| **Leah** | Level 6 | 15 years |
| **Elaine** | Level 8 | 1 year |

Their roles in the setting included planning and implementing play-based learning, supporting children's social and emotional development, and communicating with families. Neither educator had prior experience with CT or designing play with programmable robotics kits. However, both expressed interest in exploring how digital technologies could be integrated into their existing play-based pedagogy. Their participation in the study was voluntary, and they were invited to act as co-designers rather than implementers of a pre-defined programme. Together, we collaborated to plan, enact, and reflect on PRK-based play experiences during the six-week intervention.

### *3.3.3 Child Participants and Group Composition*

The children who took part in the purposeful play-sessions were those who were already enrolled in the participating educators' group. In total, eleven children aged 3-5 years participated at various points across the twelve play-sessions. All eleven children were

participating in the government funded ECCE Programme which offers two years of free preschool. Some of the children were in their first year and others in their second year (Table 10).

**Table 10: Age Profiles of Child Participants**

| Child participant (CP) | Age at beginning Play-session 1 | ECCE year 1 or year 2 |
|---|---|---|
| CP1 | 5yrs 2 mo | 2 |
| CP2 | 4yrs 11mo | 2 |
| CP3 | 4 yrs 9mo | 2 |
| CP4 | 4yrs 8mo | 2 |
| CP5 | 4 yrs 3mo | 2 |
| CP6 | 4 yrs | 1 |
| CP7 | 3yrs 11mo | 1 |
| CP8 | 3yrs 10mo | 1 |
| CP9 | 3yrs 8mo | 1 |
| CP10 | 3yrs 2mo | 1 |
| CP11 | 3yrs 1mo | 1 |

During each of the twelve play sessions, the children typically engaged in small groups of 2–4 participants, and sometimes individually, depending on their interests and the nature of the PRK activity. From Week 3 onwards, following the educators' recommendations, the format of the sessions was adapted: instead of a one-hour session with all of the children, each session was divided into two 30-minute blocks (9:30–10:00 and 10:00–10:30). The educators facilitated the children's decision making on which session to attend, which fostered their agency. Each session followed a structured and consistent format. It began with a brief whole-group circle (approximately 5 minutes), where I guided children through the assent process using an assent chart (Appendix V). Children who wished to participate indicated their consent by placing a sticker on the chart, while those who did not wish to participate were supported to engage in alternative activities with other educators in the setting. This aligned with Aistear's (NCCA, 2024) Principle: Agentic Global Citizens and Theme: Wellbeing Aim 4. that children have "agency and express choices, preferences and

make decisions for themselves and their communities whilst respecting diversity, equity and inclusion." (p. 23). This was followed by a whole-group activity (approximately 10 minutes), in which I introduced the scenario for mTiny, modelling the problem solving and sequencing steps and encouraging the children to think back to the previous play sessions and programming they tried. The educators and I scaffolded the children, inviting them to explore, observe one another, and collaborate through suggestions and peer support. The final phase of the play session consisted of small-group work (approximately 10 minutes), where the children were invited to co-create their own map block arrangements for mTiny based on a given scenario. During this phase, the educators and I supported children's exploration, tinkering, and debugging through guided participation.

Group composition varied from session to session, reflecting the setting's play-based ethos that children had freedom to choose learning experiences. Consistent with the ethics and children's rights framework outlined in Section 3.8, participation was voluntary; children could choose to join the PRK-related activities or engage in alternative play experiences. The children's engagement varied depending on attendance, interest, and ongoing assent. Consequently, not all children participated in every session, and the dataset reflects varying patterns of engagement rather than a fixed cohort (Appendix U). It was not a requirement that all children attend every session as the focus of the research was not on assessing individual children's CT, but rather on understanding how educators designed and enacted CT-rich play opportunities and gained understanding of how to support children's development of CT,

### *3.3.4 The Six-week Intervention*

The case focused on a six-week co-design intervention in which two educators and eleven children engaged in twelve PRK-based play sessions, supported by weekly planning meetings and post-session debriefs. This design aligns with research on early childhood computational thinking interventions using PRK by Hall and McCormick (2022) and Gerosa

et al. (2022), which found that sustained programmes of four to twelve weeks more developmentally appropriate and effective for maintaining young children's engagement than longer, less intensive initiatives. Across this period, the educators and I collaboratively designed, enacted and reflected on purposeful play experiences that used PRK to support young children's computational thinking within the everyday routines of the ECEC setting. The play-session content was structured to progressively build key computational thinking concepts such as algorithmic thinking, pattern recognition and debugging. A detailed overview of the play-session format is outlined in Appendix V, and content focus over the twelve sessions is delineated in Appendix W. These iterative cycles of planning, play and reflection are described in more detail in Section 3.4, Stage 3: Enact Intervention, which outlines how the intervention was implemented within the Design-Based Research (DBR) framework. Insights from each play-session informed subsequent planning decisions, enabling responsive adaptation of the learning experiences. These design decisions for subsequent sessions were informed by ongoing observations and collaborative reflection with educators, enabling iterative refinement of the complexity of PRK tasks and the pedagogical supports to foster CT (see Appendix X).

## 3.4 Implementation of the Co-design Intervention

The research design followed the design-based research stages of preparation, design, enactment, and retrospective analysis (see Figure 11).

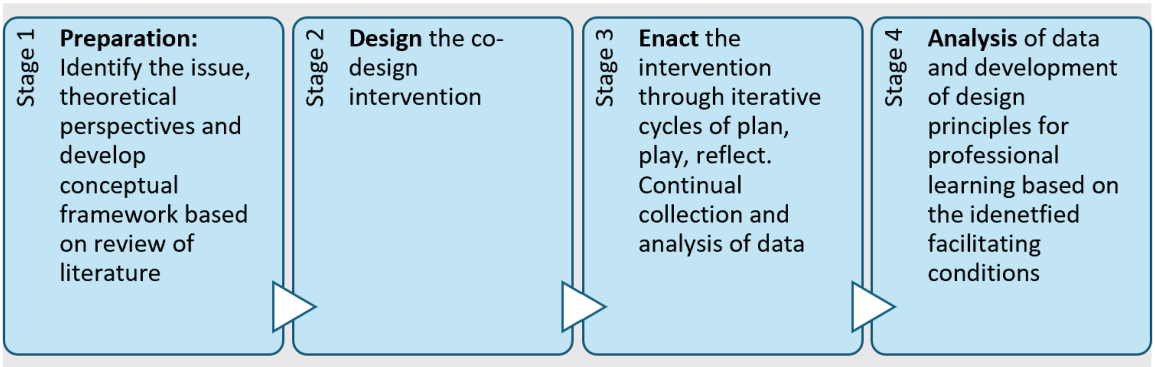



**Figure 11 Research Design Stages (based on Reeves, 2006; Baaker, 2018; Papavlasopoulou et al., 2019)**

**Stage 1: Preparation**

This stage took place between April and November 2023 and involved analysing the practical problem through policy and literature reviews to identify the research gap regarding the development of young children's CT through play with PRK in ECEC settings in Ireland. During this stage, I developed knowledge and skills in CT, PRK, and how to support the educators, as well as in research methods and data collection. I conducted a literature review to identify theoretical perspectives and practical problems, which led to the development of the conceptual framework.

**Stage 2: Design Intervention**

During Stage 2, the research design and the intervention were developed. This included designing the educator workshop (Appendix A) and the initial outline of CT and PRK purposeful play-sessions for educators and for children. I submitted the study for ethical approval and refined the design of the intervention accordingly. This stage took place between August and December 2023.

**Stage 3: Enact Intervention**

Stage 3 (Figure 12) involved implementing the intervention in the ECEC setting and working with the educators to co-design learning experiences that supported young children's development of CT through purposeful play with PRK. Over a six-week period (January–March 2024) (Appendix B), two educators and eleven children participated in twelve PRK-based play-sessions embedded within the normal daily routine. Prior to working with the children, the educators took part in pre-intervention semi-structured interviews and an educator workshop, which introduced key ideas about CT and PRK and explored links to their existing play-based pedagogy. Following the intervention, post-intervention interviews were conducted to capture shifts in beliefs, knowledge and practice.

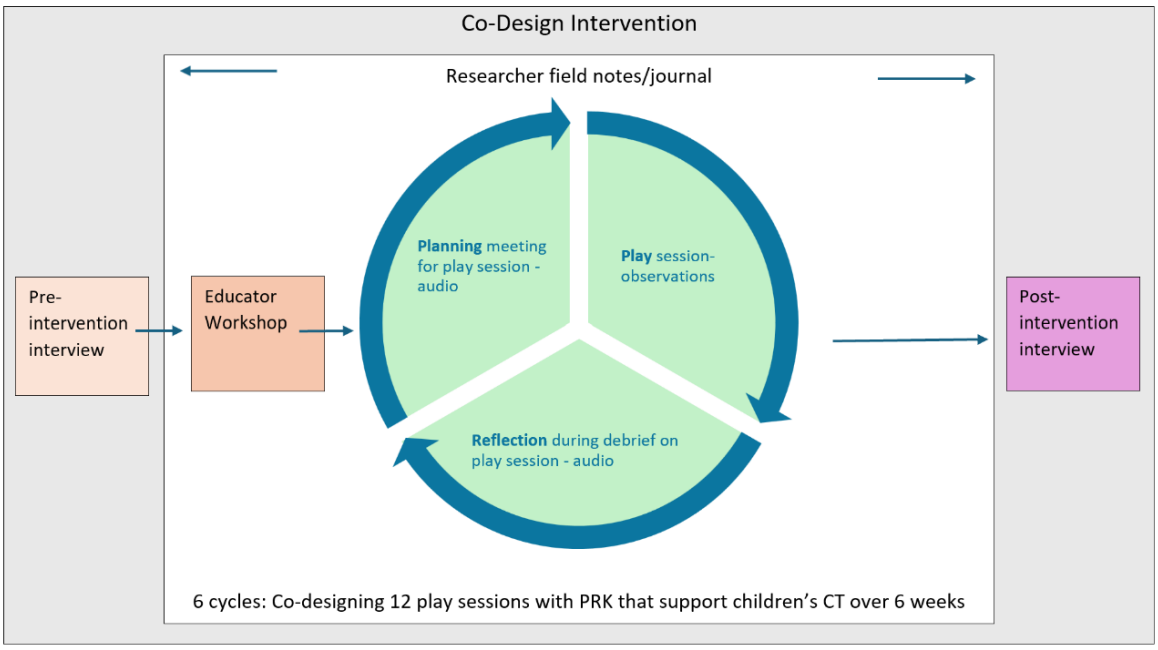



**Figure 12: Stage 3 Enacting the Co-design Intervention**

During Stage 3, we engaged in iterative cycles of planning, play and reflection. The weekly debriefing sessions and planning meetings guided adjustments to the design and implementation of the CT play-sessions over the six weeks. Weekly planning meetings were used to co-design purposeful play with PRK with intentional learning goals to support CT-related skills such as algorithmic thinking, debugging and pattern recognition. These plans were then enacted in the play-sessions with children. Immediately after each play-session, debrief meetings provided a space for the educators and me to reflect on children's engagement and the educators' pedagogical strategies. Insights from these reflections informed adjustments to subsequent sessions, shaping both the evolving intervention design and the educators' developing CT pedagogy. Throughout Stage 3, qualitative data was collected through pre- and post-intervention interviews, audio-recorded planning and debrief meetings, structured child observations and my researcher field notes (Section 3.5). This data was analysed and the findings supported Stage 4's development of professional learning design principles.

**Stage 4: Development of Design Principles**

Stage 4 took place between June 2024 and November 2025. It involved communicating the findings and analysis and developing design principles for educator professional learning, based on the emergent facilitating conditions. This final stage drew together reflections from the previous stages and addressed the research question concerning the facilitating conditions needed to support educators to design purposeful play with PRK as part of supporting young children's CT development in the Irish preschool context. It also focused on identifying characteristics and features that could be valuable in the development of professional learning programmes for educators.

## 3.5 Data Collection: Qualitative Multimethod

Consistent with the study's qualitative, multimethod, and design-based orientation, multiple forms of data were collected to provide a rich, contextualised understanding of the co-design process, the educators' professional learning, and children's developing computational thinking (CT). This approach aligns with the interpretivist and constructionist worldview underpinning the study, in which knowledge is viewed as co-constructed through dialogue, reflection, and experience. Access to the research site was negotiated through initial engagement with the manager of the participating early childhood setting. During the initial meeting with the educators, the aim and design of the study were outlined, which included the purpose of the research, the nature of the co-designed play sessions, and the expectations of participation for educators, children and me as researcher-mentor. I was introduced to the children in their familiar learning environment by the setting manager prior to the intervention, during the week of 22nd January 2024, which helped to establish a connection and build trust and transparency regarding participating in the research study (Walsh et al., 2026). Ethical approval (Appendix L) was secured prior to data collection, and informed consent was obtained from all participating educators, as well as from parents/guardians on behalf of the children. Assent procedures were also embedded within the play sessions to

ensure that children's ongoing willingness to participate was respected (Appendix O). This approach to access is aligned with ethical principles of respect, voluntary participation, and informed decision-making in research with young children (Walsh et al., 2026).

Building trust and maintaining positive relationships with both the educators and children was an ongoing and intentional process throughout the study. Time was spent in the setting prior to and during the intervention to establish rapport, enabling the participants to become familiar with my presence and role. In line with the Walsh et al. (2026) guidance emphasising the importance of flexibility, time, and an unhurried approach to relationship-building, I was present in the setting three days per week (Tuesday, Thursday, and Friday), 3-4 hours at a time, for the six-week duration, including two play session days and one planning meeting day (Appendix B). Time was deliberately built into this schedule to support the development of authentic relationships. In practice, this involved arriving early, engaging informally with educators, and being present during everyday routines such as children's arrival with their parents/guardians. I was also invited to participate in aspects of the social life of the setting, such as celebrations and informal gatherings, which further supported rapport-building and demonstrated respect for the community. The collaborative nature of the design-based research approach strengthened these relationships, positioning the educators as co-designers. This was further reflected in practices already embedded within the setting, such as the educators taking photographs of children's engagement in play with the PRK and documenting these moments as learning stories to share with families. These practices supported continuity between the research and the setting's pedagogical approaches, reinforcing trust and shared ownership. Open communication and my responsiveness to educators' insights, and interpretations of the children's strengths, interest and needs, supported my attunement to the children's communication, gestures, emotional wellbeing (Walsh et al., 2026).

With the children, trust was supported through the predictable routine of the play sessions on Tuesdays and Thursday mornings; these days and times were intentionally chosen by the educators to best align with the children's established routine. The balance of whole and small group elements within the play session structure reflected familiar curriculum and pedagogical strategies, supporting the children's engagement At the end of the intervention I left three mTiny kits along with the play session resources we had co-created (Appendix, A, N, Q, V, Y). In addition, I maintained contact with participants beyond the formal intervention period, returning to the setting a few times, between March and May 2024, to reconnect with the managers, educators and children and in July 2024 to provide a CT and PRK workshop to two other educators in the setting. This ongoing engagement reflected a commitment to sustaining relationships beyond data collection. Overall, this relational and flexible approach contributed to a supportive research environment and enhanced the authenticity and depth of the data collected. Within this relational and ethical framework, each data collection method (Table 11) provided complementary perspectives, supporting triangulation and enabling the iterative cycles of planning, enactment, reflection, and redesign central to Design-Based Research (DBR).

**Table 11: Data Collection: Methods, Purpose and Tools**

| Data collection method | Purpose | Data collection tool |
|---|---|---|
| **Pre- and post-intervention interviews** | Captured educators' evolving beliefs, knowledge, practices and professional learning | Audio-recorded interviews, transcribed verbatim |
| **Planning meetings and debrief sessions** | Documented educators' co-design decision making and reflection on play-sessions | Audio-recorded transcripts; co-designed artefacts (e.g., play-session plans) |
| **Structured child observations** | Recorded children's learning moments, CT behaviours and dispositions during the play-sessions with PRK, supporting educators' co-design planning and reflection | Observation checklist tool (Appendix), narrative field notes; photographs of programming sequences and robots in action |
| **Participant observations and field notes** | Captured researcher observations and reflection on educators' learning, practice and engagement with the co-design | Researcher Journal |

The interviews captured educators' evolving knowledge, practices and beliefs, observations recorded moments of learning and practice, planning meetings and debrief sessions documented educator decision making and reflection and my researcher journal captured participant engagement and my own reflections. Meaning was constructed through the synthesis of all data sources; no single method dominated. The following sections describe each data collection method and explain how it was integrated within the DBR process.

### *3.51 Semi-Structured Interviews*

Semi-structured interviews were conducted with participating educators before and after the intervention: the pre-intervention interviews took place during the week of 22nd and 24th January 2024, and the post-intervention interviews took place on 26th March 2024. All interviews were conducted in person within the research setting at times convenient for the educators, with the setting manager arranging cover for their cohort of children. The interviews lasted between 30 and 50 minutes. The interviews aligned with the professional knowledge perspective (Campbell-Barr, 2019) within the conceptual framework, foregrounding educators' values, pedagogical knowledge, and professional learning. The pre-intervention interviews explored the educators' existing knowledge, skills and values (attitudes and beliefs) and expectations in relation to ECEC pedagogy, CT pedagogy and using PRK digital technologies with young children. The pre-interview schedule was informed by the literature review, in particular Venkatesh et al. (2003) *Unified Theory of Acceptance and Use of Technology* (UTAUT) model (Appendix C). The post-intervention interviews examined changes in understanding, shifts in practice, and reflections on the co-design experience (Appendix D). These were triangulated with data from the co-design process to illuminate changes in the educators' CT related beliefs and practices.

### *3.5.2 Planning Meetings and Debrief Sessions*

Collaborative planning and debrief meetings were integral to the DBR process. Together, the educators and I co-designed purposeful learning experiences, reflected on implementation of each play-session, and revised plans for subsequent play-sessions. The debriefs occurred after every play-session, with each session lasting approximately 10–15 minutes and taking place in a quiet space within the early childhood setting, with the manager arranging cover for the children during this time. The planning meetings were also held in the setting, on Friday afternoons during the educators' scheduled planning time and typically ranged in duration from 30 to 45 minutes. and the planning meetings took place weekly. The meetings were audio-recorded to document the co-construction of ideas and to capture the dialogue that underpinned design decisions. Audio recording offered an unobtrusive way for educators to share their perspectives (Creswell and Creswell, 2023), while also allowing me to participate fully in the conversations in the moment and later return to the recordings for detailed interpretation and analysis. This choice was therefore both methodological and practical: it supported rich, dialogic data while preserving my dual role as researcher and co-designer. The weekly planning meetings followed a clear agenda and purpose: to review the play-sessions conducted so far and to use these reflections to make plans or adaptations for the next week's sessions. Data from these meetings comprised the audio-recorded discussions, the documented agenda and minutes, and the agreed plans for subsequent play-sessions. Drawing on sociocultural learning theory (Rogoff, 1990), these sessions embodied guided participation and shared meaning-making, where professional dialogue became a means for the educators' learning and iterative design refinement.

### *3.5.3 Strucured Child Observations*

Structured observations were conducted during the twelve co-designed play-sessions to capture how the children engaged with PRK and CT skills such as algorithmic thinking, pattern recognition, debugging, as well as the educators' pedagogical strategies. Prior to data

collection, I was introduced to the children by their educators as a researcher who would be participating in and observing the play sessions. Time was spent in the setting to familiarise the children with my presence, supporting rapport and minimising disruption to their typical interactions. This positioning was important in establishing a comfortable and ethically responsive environment for observation. During the sessions, I adopted a participant-observer role, consistent with Robson (2011). While leading elements of the play-sessions (e.g., demonstrations and scaffolding), I simultaneously observed children's engagement, interactions, and emerging CT behaviours. At other points, particularly during child-led exploration, I stepped back to observe more closely, intervening only when necessary to support participation or extend learning. This shifting role enabled the capture of both naturally occurring interactions and scaffolded learning moments.

The observation data were triangulated with data from the other sources to provide a rich picture of significant learning and practice moments for the educators based on the children's CT engagement. Relevant triangulated moments were presented as learning stories within Chapter 4. An observation tool was developed to record both the occurrence of specific CT behaviours and the level of educator support required (Appendix E). The checklist feature was used to document the CT skills children demonstrated, while open sections on the form were used to capture brief narrative accounts of the learning moment and the unfolding interactions, acknowledging the contextual and relational nature of play-based CT learning. Robson (2011) notes that structured observations provide a useful way to observe behaviours and require a coding system such as rating scales to record whether a behaviour occurred. In this study, the checklist and rating scale were adapted from coding schemes previously developed in this area (Bers, Flannery, Kazakoff, and Sullivan, 2014), with further refinements informed by the Seven Powerful Ideas of CT (Sullivan, Bers, and Mihm, 2017; Pugnali, Sullivan, and Bers, 2017).

When designing the observation tool, I drew on Poveda's (2019) discussion of shadowing as an alternative to video recording for documenting children's engagement with digital technologies. While video can capture rich non-verbal behaviour, it also generates large data sets that are time-consuming to analyse and raise additional ethical and practical concerns. The structured observation form combined a pre-specified checklist of key CT skills, behaviours, and dispositions with space for short narrative descriptions and photographs of the code, programmes created, and the robot in action. In line with Poveda's suggestion that combining images with other data-collection techniques can maximise the detail of the data, these visual records functioned not only as research data but also as resources within the co-design process. They made children's CT activity visible to the educators, supporting them to build their knowledge and understanding of CT and to explain and elaborate on what went well (or did not) when reviewing each session and making decisions for subsequent play-sessions. This design aligned with Poveda's emphasis on pre-defining the focus of observation and recording targeted episodes, and it balanced the need for systematic data with the practical and ethical considerations of observing young children.

### *3.5.4 Participant Observations and Field Notes*

Throughout all DBR cycles, I maintained a detailed field journal containing descriptive notes, reflexive observations, and analytic reflections. These field notes complemented the structured observations by capturing aspects of participation that were not easily codified, such as relational dynamics, contextual influences, and shifts in educator thinking. As an engaged participant-observer, my reflections included immediate impressions after sessions, methodological adjustments, and evolving interpretations of educator–child interactions. Field notes and reflective writing aligned with Berman's (2013) ideas of the conceptual framework as a living scaffold, supporting reflexivity and coherence throughout the research. They also reflected the interpretivist emphasis on the researcher as an instrument of inquiry, acknowledging the influence of positionality on interpretation and decision-

making. These reflections were analysed alongside other data to provide contextual information and to trace how the educators' learning and decision-making evolved across the cycle (Appendix F), supporting interpretation when individual data sources were brought together for analysis. Taken together, the interviews, planning and debrief meetings, structured child observations, and my researcher field notes constituted a rich, multi-layered qualitative dataset. Audio recordings were transcribed verbatim, observation checklists and narrative notes were collated, and visual artefacts (such as photographs of children's programming sequences and robots in action) were organised alongside my researcher journal entries. This integrated dataset provided complementary perspectives on the co-design process, educators' professional learning, and children's CT engagement. The following section outlines how these data sets were analysed using reflexive thematic analysis (Braun and Clarke, 2006, 2019).

## 3.6 Data Analysis: Reflexive Thematic Analysis

All data generated in the study (Table 12), including interview transcripts, audio-recorded planning and debrief meetings, structured child observation records, visual artefacts (such as photographs of programming sequences and robots in action), and my researcher field journal entries, were analysed using reflexive thematic analysis (Braun and Clarke, 2006, 2019, 2021).

**Table 12: Data Sources and Types**

| Data Sources | Number of Data Types |
|---|---|
| Pre-interview | 2 audio transcripts |
| Post-interview | 2 audio transcripts |
| Planning meetings | 6 audio transcripts |
| Debrief sessions | 10 audio transcripts<br><br>2 written documents |
| Research journal | 6 written documents |
| Structured observations | 94 written documents |

Given the volume and diverse range of data generated across multiple design cycles, careful data organisation and management procedures were implemented prior to and throughout analysis. All data sources were systematically organised by type (e.g. interviews, observations, researcher journal) and by design-based research cycle (Weeks 1-6) and play sessions 1-12. Audio recordings were transcribed verbatim, and files were assigned consistent identifiers, including use of dates, to enable cross-referencing across datasets (Figure 13).

| File identifiers | Example of files labels from the research folder |
|---|---|
| **Interviews**<br>Pre-interview files labelled as<br>– Leah (LE)<br>– Elaine (ED) | Interview 1 LE 22/1/24<br>Interview 2 ED 24/1/23 |
| **Planning Meetings**<br>Audio and transcribed files labelled identically:<br>Week 4<br>– Planning Meeting 4 (Plan M 4) | Plan M 4 23rd Feb.mp3<br>Plan M 4 23rd Feb.docx |
| **Debrief sessions**<br>Audio and transcribed files labelled identically.<br>Week 4<br>– Debrief for Play Session 7 on the 27th February (Debrief PS7)<br>– Debrief for Play Session 8 on the 29th February (Debrief PS8) | Debrief PS7 27th Feb.mp3<br>Debrief PS8 29th feb.mp3<br>Debrief PS7 27th Feb.docx<br>Debrief PS8 29th feb.docx |

**Figure 13: Labelling data files**

Data were stored securely, using my DCU student credentials, within a structured digital folder system (DCU Google Docs) (Figure 14), allowing for efficient retrieval and supporting the iterative nature of the analysis. This ongoing organisation facilitated the integration of multiple data sources and contributed to the transparency and traceability of the analytic process. The organised data were subsequently uploaded to NVivo to facilitate my engagement with Phase 1 and Phase 2 of reflexive thematic analysis, as outlined in Table 13 and, discussed in Sections 3.6.1 and 3.6.2.

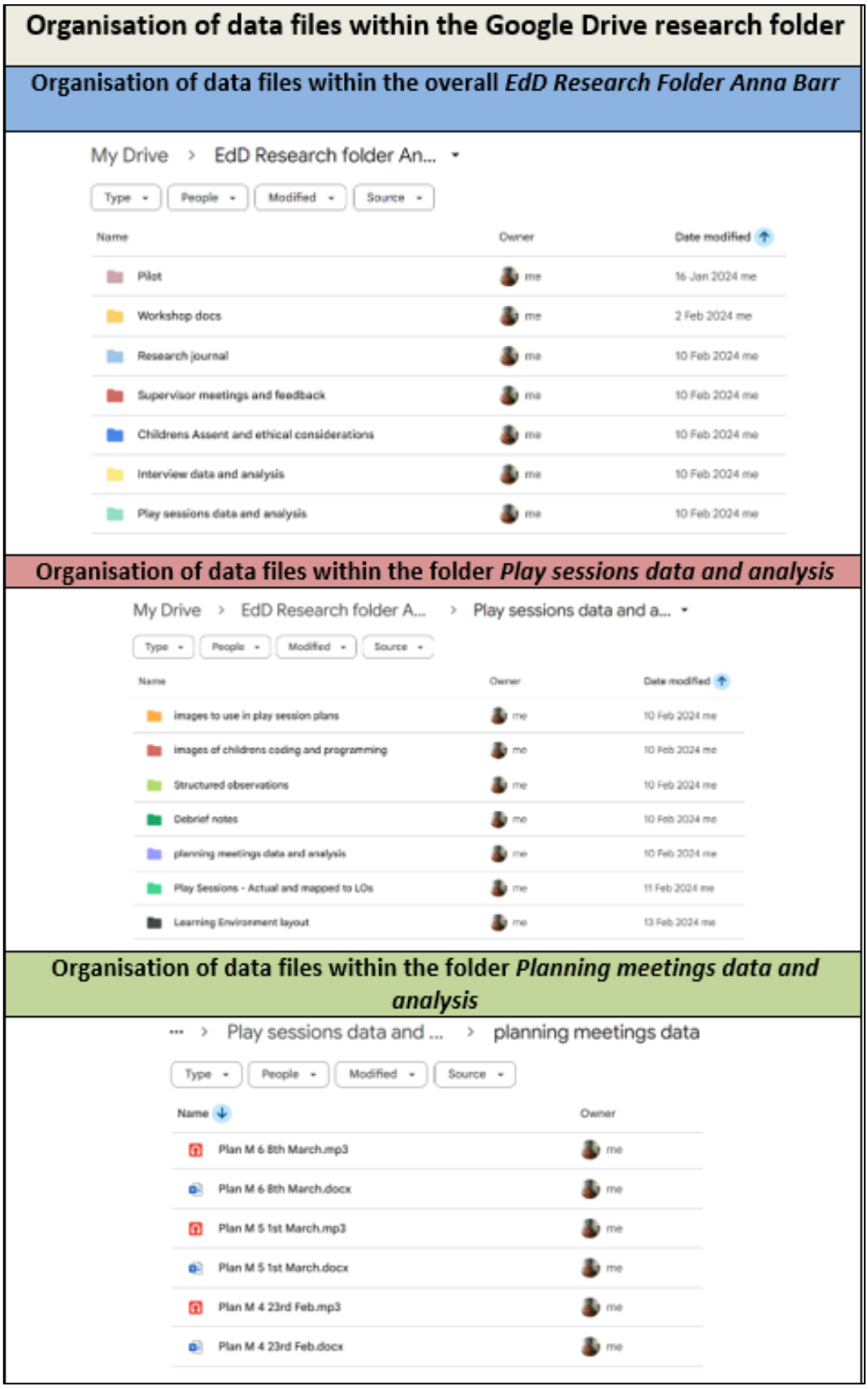



**Figure 14: Organisation of data files within the Google Drive research folder**

Treating these multimethod data as an integrated qualitative dataset was consistent with the study's interpretivist, constructionist orientation and with the iterative DBR cycles of planning, enactment, reflection and redesign. Reflexive thematic analysis offered a flexible yet rigorous way of identifying patterned meanings across DBR cycles and data sources, while attending to context, relationships and the co-designed nature of the learning experiences. Throughout, I adopted a reflexive stance, acknowledging my role as researcher-mentor and the ways my interpretations were shaped by ongoing engagement with educators, children and the evolving intervention. Data analysis commenced in April 2024, once the intervention finished and data from the post-intervention interviews had been collected. Reflexive thematic analysis helped me notice and interpret patterns and meanings across the wide range of data, including connections I had not anticipated in advance (Braun and Clarke, 2022). An inductive approach underpinned the analysis, moving from detailed, context-specific accounts towards more general understandings of how the co-design process influenced educators' professional knowledge, practices and beliefs about young children's opportunities to develop CT through purposeful PRK play.

Following Braun and Clarke (2019), I used the six phases of reflexive thematic analysis as a flexible guide rather than a strict step-by-step procedure, moving back and forth between phases as I reflected on the data and the research question and sub-questions. The six phases of the analytic process are outlined below. As Braun and Clarke (2019) emphasise, although they are presented as distinct for clarity, the actual process was recursive rather than linear (Table 13).

**Table 13: The Six Phases of the Analytic Process (Based on Braun and Clarke, 2006, 2019)**

| Reflexive thematic analysis phase (Braun and Clarke) | Purpose (Braun & Clarke) | How this study enacted the phase |
|---|---|---|
| **Phase 1 Familiarisation with the data** | Become immersed in the data; get an overall sense of content | Transcribed audio; repeatedly listened to recordings; re-read interviews, observations, and journal entries; wrote memos and reflexive notes. |
| **Phase 2 Generating initial codes** | Systematically code interesting features across the dataset | Inductive coding in NVivo and by hand; coded by data type; identified semantic and latent meanings; refined overly broad and overly fine-grained codes. |
| **Phase 3 Searching for themes** | Collate codes into potential themes | Built significant code clusters per data type; then reviewed across the whole dataset; produced seven overarching coding clusters and initial theme ideas. |
| **Phase 4 Reviewing themes** | Check themes against codes and data; refine theme structure | Used thematic maps and triangulation to refine boundaries, resolve overlaps, and focus on analytic importance rather than prevalence. |
| **Phase 5 Defining and naming themes** | Clarify the "story" of each theme; generate clear theme names | Mapped each theme to a central organising concept; created theme concept maps; developed concise, meaningful theme names and emerging sub-themes. |
| **Phase 6 Producing the report** | Write a coherent, persuasive analytic narrative | Treated writing as continued analysis; interwoven data extracts and interpretation; combined results and discussion, ordered themes to tell a cumulative story. |

I developed the themes inductively, as part of my interpretive work, from what emerged in the data. The codes and themes therefore reflect my construction of patterned meaning across the dataset, consistent with the study's constructivist epistemology. I did not base codes and themes on how often something appeared in the data, instead, I focused on how particular excerpts responded to the research and sub-questions (Braun and Clarke, 2022). Coding and theme construction were carried out using both NVivo and manual, written methods. NVivo was used to store, organise and retrieve the large volume of data and to view and check coding labels, categories and developing themes. At no point did the software replace my judgement as researcher; manual grouping and regrouping of codes ran alongside NVivo

use, reinforcing my sense of ownership of the analysis (Braun and Clarke, 2019). Together, NVivo outputs and manual records formed a transparent audit trail, documenting how the analysis developed over time (Lincoln and Guba, 1985). The analysis was iterative and prolonged, involving multiple rounds of coding and theme refinement before final themes were agreed (Figure 15).

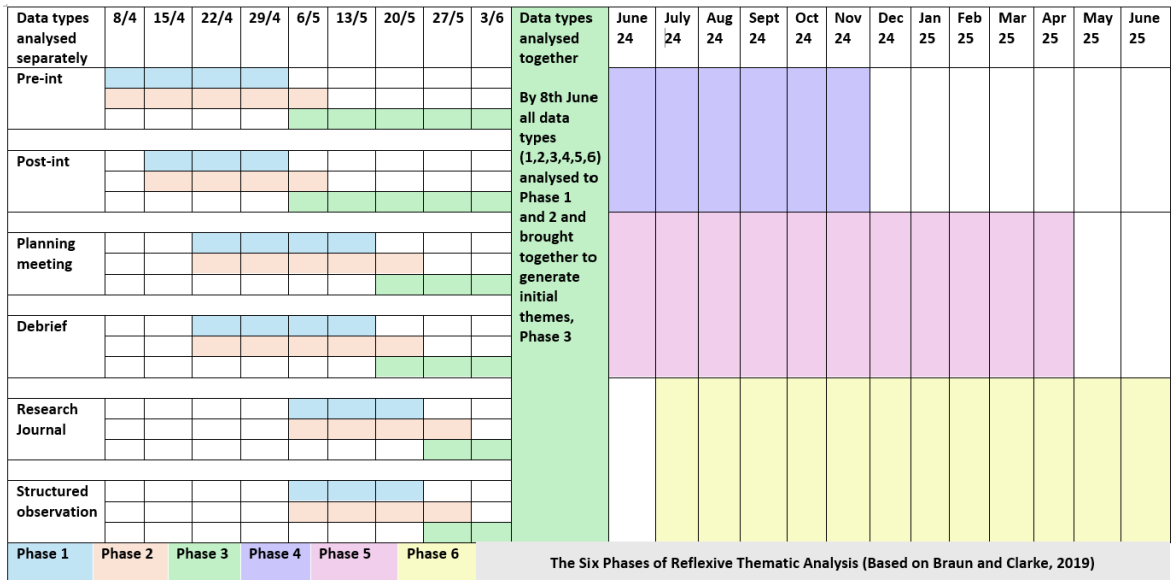



**Figure 15: Six Phases of Reflective Thematic Analysis Timeline (based on Braun and Clarke, 2019)**

Given the volume and diversity of data generated, careful organisation and management procedures were implemented prior to analysis. All data sources, including interview transcripts, observation records, field notes, planning and debrief meeting notes, and visual artefacts, were systematically organised by data type and by design cycle. Data was stored securely and organised into a structured folder system to support ease of retrieval and iterative analysis. In keeping with the design-based research approach, data organisation was ongoing and cyclical, aligning with phases of planning, enactment, reflection, and redesign. This facilitated the integration of multiple data sources during analysis and supported the identification of connections between educator decision-making, pedagogical practice, and children's computational thinking engagement. This systematic approach to data management ensured transparency, traceability, and rigour throughout the analytic process.

### *3.6.1 Phase One: Data familiarisation*

The first step in the analysis was transcribing the audio recordings of the interviews, planning meetings and debrief sessions. This was a time-consuming process, due to accents, multiple speakers during the planning meetings and debriefs, specialist terminology and contextual references. However, the repeated replaying and careful listening helped me to become familiar with, and immersed in, the data. During the data familiarisation phase (13 April–29 April 2024) I also reviewed the observation records and research journal entries, reading them several times and noting significant thoughts in my project journal. I engaged critically with the material, writing memos to capture patterns of repetition and anything that seemed important, surprising or significant in relation to the developing dataset. I revisited Braun and Clarke's (2022) guidance at this stage to support a reflexive stance, and I continued to return to the data up to 13 May to re-familiarise myself as needed during phase two of the analysis.

### *3.6.2 Phase Two: Systematic Data Coding*

Phase two involved systematically coding the data to capture ideas and meanings relevant to the research question. Using an inductive, data-driven approach, I worked through the dataset assigning short, descriptive code labels to segments of text. Coding was documented in NVivo, which I used to organise the data by type (interviews, planning meetings, debriefs, research journal, structured observations), highlight meaningful extracts and store them under code labels so that patterns could be retrieved and reviewed efficiently. Appendix G illustrate examples of this work in progress.

I coded each data type separately and returned to each dataset more than once to review and refine the coding. As a result, some codes and code labels shifted over time, particularly those attached to the post-interview data, where my initial attempt to mirror the pre-interview codes produced labels that were too broad. I also attended to both semantic (surface-level) and latent (underlying, implicit) meanings. Where deeper interpretation was needed, I added

memos in NVivo to capture my developing understanding and to help articulate the significance of particular extracts. During this review process, I found that some codes were too broad, especially in the research journal and structured observation data, where very few codes had been applied and important distinctions were being overlooked. In contrast, the interview, planning and debrief data initially had a very large number of highly specific codes, some attached to only one data segment (Table 14).

**Table 14: Number of codes per data source**

| Data Source | Number of code labels |
|---|---|
| Pre-interview | 39 |
| Post-interview | 56 |
| Planning meetings | 32 |
| Debrief sessions | 40 |
| Research journal | 4 |
| Structured observations | 3 |

Following Braun and Clarke's (2022) guidance that overly unique codes can indicate coding that is too fine-grained, I merged and renamed some codes and grouped related codes under broader labels (Appendix H). All codes and code labels were then systematically reviewed by data type to identify patterns of meaning. These patterns were used to develop preliminary code clusters, which supported the generation of candidate themes in Phase Three. This clustering process was completed using NVivo and by collating clusters and extracts into a booklet.

### *3.6.3 Phase Three: Generating Initial Themes (from coded and collated data)*

The significant code clusters identified for each data type in Phase Two were then brought together and reviewed as a single dataset. I looked for cross-cutting patterns of meaning,

which led to the development of seven higher-order coding clusters that synthesised the analysis (Table 15).

**Table 15: Phase Three Analysis: Development of Seven Coding Clusters**

| Seven coding clusters |
|---|
| 1. The educators' approach to learning to use Programmable Robotics Kits |
| 2. The educators' pedagogical beliefs and values and approaches |
| 3. The ways the educators think children learn best |
| 4. The educators views on young children playing with digital technology and programmable robotic kits in ECEC |
| 5. What the educators learned about Computational Thinking for 3-5 year olds |
| 6. Challenges for the educators and barriers to developing computational thinking and play with programmable robotic kits |
| 7. What might influence the educators to continue |

Developing these seven coding clusters was a long and thorough analytic process, focused on identifying patterned meaning in relation to the research and sub- questions. I began by reviewing the pre- and post-interview clusters together to spot patterns and possible themes, then repeated this process with the planning meeting clusters, the debriefs, the research journal and finally the structured observations. Moving the analysis into booklets and onto flip-chart paper with colour-coded post-it notes made it easier to see potential themes and sub-themes visually (Appendix I). At this stage, the seven coding clusters were not treated as themes in their own right but as provisional groupings that pointed towards possible thematic areas such as: The co-design process; Learning by doing it with the children, Play with PRK aligns with their ECEC values. These initial thematic areas were collated with relevant data extracts into theme-cluster booklets. The work of clarifying and refining theme boundaries continued into Phase Four, where themes and sub-themes were further developed and sharpened.

### *3.6.4 Phase Four: Developing and Refining Themes*

In Phase Four, I reviewed, revised and further developed the initial themes. I examined each theme in relation to the research and sub- questions, the coded data and the wider literature, focusing on analytic importance rather than frequency. Issues that appeared only occasionally were still considered if they offered valuable insight, and their meaning was often supported through triangulation with other data types such as the research journal and structured observations. I used thematic mapping to visualise the overall story of the analysis (Appendix J). Mapping helped me to clarify boundaries between themes, identify overlaps and see connections across themes. For example, some initial theme ideas from Phase Three overlapped and lacked clear boundaries, which I addressed during this phase. Using colour-coded post-it notes on flip-chart paper, I moved potential themes and sub-themes around while repeatedly returning to the extracts in the theme cluster booklets. This iterative process was the main way in which the themes were refined and finalised.

### *3.6.5 Phase Five: Refining, Defining and Naming Themes*

This phase focused on analytic refinement through writing and overlapped with Phase Six. Building on Phase Four, I revisited each theme and mapped it in relation to its central organising concept: what the theme was about, what was specific and unique to it, where its boundaries lay, and how it contributed to the overall analysis. I then identified concise names for each theme that captured its essence. I also developed an initial concept map for each theme (Appendix K) outlining what, why, how and outcome of the theme in relation to the research question. These maps provided a framework for drafting the analytic write-up of each theme. At this stage, sub-themes were not yet fully specified, but potential sub-themes began to emerge and were developed iteratively as I wrote about each theme and connected data extracts from the initial theme clusters

### *3.6.6 Phase Six: Writing the Report*

In this final phase, the writing of each theme was itself a continuation of the analysis rather than a separate write-up stage. As I drafted the thematic narratives, I repeatedly revisited and revised the themes and sub-themes, which meant moving back and forth between Phases Four and Five (Figure 16).

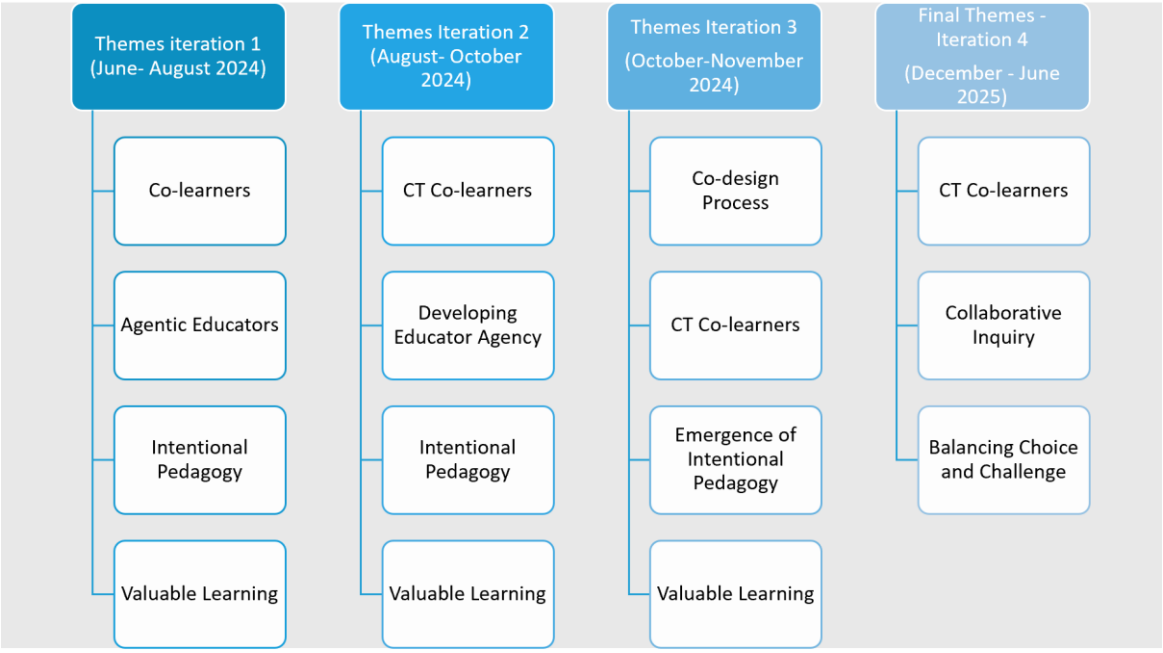



**Figure 16: Theme Iterations June 2024-2025**

This iterative process deepened the interpretation and helped refine the meanings so that the overall story of the analysis was as coherent as possible. I engaged in ongoing reflexive analysis, aiming to provide richly contextualised descriptions to help the reader make sense of the data extracts. Being very close to the data sometimes made it difficult to judge how much contextual detail an external reader would need, so I worked to balance description with interpretation. It was also important that readers outside the study could follow the account and be persuaded of the validity and quality of the analysis. To support this, I used an effective mix of illustrative learning stories, vignettes and extracts from across the dataset and analytic commentary that clearly showed how the evidence supported my claims. I also chose to combine the presentation of findings, analysis and discussion, weaving my analytic narrative together with relevant literature. Braun and Clarke (2022) suggest that reporting

results and discussion together can be particularly effective when there are many connections between the analysis and existing research.

## 3.7 Ethical Considerations: Children and Educators

Ethical approval for this study was granted by DCU Research Ethics Committee on 6th January 2024 (Appendix L). Conducting research in an early childhood education and care (ECEC) setting, and involving young children and their educators, carried particular responsibilities. The study was underpinned by the principles of the UN Convention on the Rights of the Child (UNCRC), including children's rights to provision, protection and participation, and by relevant ethical and child safeguarding and participation guidance (DCYA, 2012; ERIC, 2023; GoI, 2020; TUSLA, 2023). In keeping with the interpretivist, design-based orientation of the study, ethics was treated as an ongoing, relational process rather than a one-off hurdle at the point of formal approval. This involved designing developmentally appropriate approaches to children's information and assent, supporting educators' voluntary, informed participation while acknowledging potential professional risks; and ensuring robust procedures for data protection, consent and the right to withdraw.

### *3.7.1 Child Participants*

In this design-based study, ethical participation for children was understood as more than the acquisition of parental consent. In line with children's rights frameworks and contemporary early childhood research (e.g. GoI, 2023, O 'Farrelly and Tatlow-Golden, 2022; Arnott et al., 2020; Pyle and Danniels, 2015), the research design sought to support children's own informed, ongoing choice about taking part in the PRK robot play-sessions. This involved developing child-friendly information about the research, providing concrete mechanisms for children to express assent and dissent, and remaining attentive to children's verbal and non-verbal cues throughout the play.

### Image-based information booklets

To introduce the research to children in a developmentally appropriate way, I created an image-based information booklet describing the PRK robot play-sessions (Appendix M) and a second visual booklet to introduce mTiny the robot panda (Appendix N). O'Farrelly and Tatlow-Golden (2022) argue that young children's capacity to make decisions about research participation is often underestimated, and that simple illustrated booklets can act as material artefacts that scaffold both children's understanding and adults' recognition of children's rights to choose. Drawing on this work, the booklets used photographs. images and simple pictorial sequences to show the robots and the kinds of activities children might engage in. The booklets were positioned as a shared resource to support conversation; introduced in small groups enabling children to look through the images at their own pace, ask questions and comment on what they noticed. Following Pyle and Danniels' (2015) critique of written "child assent forms" that mimic adult consent procedures, children were not asked to sign anything. Instead, assent was expressed orally and through children's engagement with the booklets and their subsequent choices about whether to join the robot play.

### Visual assent chart and ongoing assent

In addition to the booklets, I developed a visual assent chart (Appendix O) that was used at the start of every play-session, so that assent was negotiated and renegotiated over time, rather than a single decision at the beginning of a study (Arnott et al., 2020; Pyle and Danniels, 2015). The chart outlined our research agreement using pictorial images and words (for me to read out) and provided two simple options, to join the robot play or choose another activity, represented through images. Children placed a sticker on the chart to show that they wanted to join the robot play today. Arnott et al. (2020) highlight the value of creative, pedagogically appropriate consent tools, such as joint ethical agreements or physical artefacts, that give children concrete ways to signal their willingness to participate and to

step out. The visual assent chart functioned in a similar way. It created a visible space within the classroom routine where children's choices about research participation were made explicit, while also helping to rebalance power by giving children a tangible way to say 'yes' or 'no'. At the beginning of each session, the children were reminded that they could change their minds at any time, and the chart was positioned so that they could revisit it if they wished. In this way, assent was treated as ongoing and revisable, rather than assumed once initial agreement had been given.

**Responding to assent decisions and non-verbal cues**

Both Pyle and Danniels (2015) and Arnott et al. (2020) stress that visual tools alone do not guarantee ethical assent; what matters is how researchers respond when children hesitate, refuse or withdraw. Throughout the PRK play-sessions, I paid close attention to children's non-verbal as well as verbal cues, such as moving away from the robot, choosing to stay with another activity, or appearing uncomfortable. These forms of dissent were respected as legitimate decisions. When a child indicated (visually, verbally or through actions) that they did not wish to join or continue, they were supported to choose an alternative activity without pressure, and their decision was accepted without negative comment. Together, the image-based information booklet, the visual assent chart and this ongoing attentiveness to assent and dissent were intended to enact a child-centred, participatory approach to research ethics.

**Wellbeing considerations**

A risk–benefit analysis was conducted at the outset of the project to identify and minimise potential harms to children, including emotional distress, disruption to routines, or inadvertent disclosure of child protection concerns. For example, risks related to the use of the mTiny programmable robotics kits (PRK) and the safe charging of devices were addressed through a risk assessment based on Tusla's Risk Management Policy Template (Tusla, 2023). Procedures followed the setting's child protection policy and national

Children First guidance (DCYA, 2012), including the requirement to report any concerns to the designated liaison person. Particular care was taken to ensure children did not feel awkward or embarrassed if they chose not to participate, or if they wished to withdraw from an activity. Alternative play options were available so that non-participation did not single children out. The methodology was designed to ensure that children were not over-researched and that their participation primarily involved engaging in playful learning opportunities consistent with their everyday experiences in the early childhood setting.

Where visual data were collected (e.g., photographs of children's programming sequences and robots in action), images were taken so that did not include children. Any visual material included in the thesis or related publications shows only anonymised work products (e.g., code cards, robot paths) and not identifiable images of children. Consent for the use of such images was included in the parent/guardian information and consent process. In addition to the more detailed written information and consent form, I also created a short visual booklet (Appendix P) for parents/guardians that summarised the key points using images and simplified text, in order to make the information more digestible and to recognise that families have varied English language and literacy fluency.

### *3.7.2 Educator Participants*

For educators, efforts were made to minimise disruption to their work and to support their wellbeing. Play-sessions were scheduled at times that fitted within the children's regular daily play-based routines. With the support of the ECEC setting manager, short debriefing meetings and weekly planning meetings were arranged during the educators' non-contact time with children. Pre- and post-interviews and the introductory workshops were scheduled at times convenient to the educators. Although participation involved additional time commitments, the study also offered professional learning opportunities for educators, including supported engagement with CT, PRK, co-design processes, and reflection on

practice. There was a potential risk to the educators' psychological wellbeing arising from power dynamics within the research context. Educators might have perceived themselves as being in a dependent relationship with the researcher, who was introducing new digital technologies and pedagogical approaches into their setting. They might also have felt that their existing practice was being evaluated or judged (Costerly et al., 2010). The study acknowledged these power relations and sought to mitigate them through the Design-Based Research (DBR) approach, which positioned educators as partners and co-designers rather than subjects of research. DBR provided structured opportunities for educators to give feedback, shape the intervention, and influence decisions as the process unfolded, thereby supporting a more collaborative and empowering relationship. My dual role as mentor and researcher was acknowledged explicitly with participants. Care was taken to avoid any implication that participation was linked to performance evaluation or assessment.

### *3.7.3 Data Protection, Consent, and Right to Withdraw*

Demographic information (e.g., names, ages) and all other personal data collected as part of this study were handled in accordance with GDPR and institutional data protection policies. No identifying information was included in interview transcripts or observation records; all names were removed, and participants were assigned pseudonyms. No identifying features of any individual were published. All participants were informed, in age-appropriate ways, about the voluntary nature of their involvement and their right to withdraw without any negative consequences. All digital data (audio files, transcripts, NVivo project files, photographs and scanned hard-copy materials) were stored on DCU password-protected, encrypted drives accessible only to the researcher and supervisors. In line with DCU policy, data will be retained for 5 years after completion of the study and then securely destroyed. Together, these measures were intended to ensure that both children and educators could participate in the research under conditions of safety, respect and confidentiality, with clear information, meaningful choice and robust protection of their data.

## 3.8 Trustworthiness of the research

Traditional concepts of validity and reliability, grounded in positivist research paradigms, are not directly transferable to qualitative inquiry. Instead, Lincoln and Guba (1985) reconceptualise these criteria within a framework of trustworthiness, arguing that validity and reliability are inherently intertwined, "there can be no validity without reliability" (p. 316) and both are necessary to ensure the integrity of research findings. Within this framework, trustworthiness is established through four key criteria: credibility, transferability, dependability, and confirmability. This study adopts Lincoln and Guba's (1985) trustworthiness framework to ensure methodological rigour and transparency, recognising the interpretive and context-sensitive nature of design-based research. The following sections outline how each of these criteria was addressed throughout the research process.

### *3.8.1 Credibility*

Lincoln and Guba (1985) emphasise the importance of establishing credibility, or "confidence in the 'truth' of the findings of a particular inquiry" (p. 290). In this research inquiry, credibility refers to the extent to which the findings accurately reflect educator and children participants' experiences and perspectives within the co-design process. Credibility was supported through several strategies, first, the study generated rich, in-depth data over a six-week period, supported by the Design-Based Research (DBR) approach and co-design methodology. This enabled prolonged engagement within the setting, including time spent building relationships and trust before and during the intervention. Second, credibility was enhanced through triangulation, drawing on Denzin's (1978) four forms of triangulation: Data source, analyst, theory and methods triangulation. Data source triangulation was achieved by incorporating multiple perspectives, including educators, children, and the researcher, across different points in the six-week intervention. Methods triangulation involved the use of semi-structured interviews, structured observations, planning and debrief

meetings, and field notes, enabling the exploration of the phenomenon through diverse methods. Yin (2013) notes that data source and methods triangulation "are likely to strengthen the validity of a case study evaluation." (p. 324) in particular when the methods have been intentionally designed to capture overlapping data. Theoretical triangulation supported the interpretation of findings from multiple conceptual standpoints, through the integrated theoretical perspective drawing on constructionist, sociocultural, and ECEC professional knowledge perspectives. Collectively, triangulation was used to explore patterns, tensions, and meanings across the dataset, with examples presented in Appendix I, J, K.

Prolonged engagement also enabled regular observation, allowing time to identify potential distortions that may have influenced the data (Lincoln and Guba, 1985). For example, my own values and assumptions, as well as the possibility of educators adopting a more passive or pleasing stance in response to my suggestions, were recognised as potential influences. These risks were acknowledged and addressed through ongoing reflexive practice, including regular peer debriefing with my doctoral supervisors through weekly meetings, during which I shared field notes and reflections (Appendix F). These discussions provided opportunities for questioning, challenging and refining interpretation. In addition, member checking with the educators was embedded throughout the research design, aligning with Creswell and Creswell's (2023) emphasis on participant validation as a key strategy for enhancing qualitative credibility. Planning meetings and play session debriefs created opportunities for educators to articulate their interpretations of events. I also integrated periodic review points within planning meetings (Appendix T) to explore whether educators recognised and agreed with my interpretations of changes in their practice and the children's computational thinking over time. This iterative approach reflects a form of ongoing or formative member checking (Creswell and Creswell, 2023), though it did not extend to the validation of final themes post-intervention, therefore the findings remain interpretive. Nonetheless, there is

evidence within the dataset of educators questioning, challenging, and contributing to decision-making, which supports the authenticity and credibility of the accounts presented (Creswell and Creswell, 2023).

### *3.8.2 Transferability*

Following Lincoln and Guba (1985), transferability is understood in terms of the extent to which the researcher provides "sufficient descriptive data…" (p. 298) to enable readers to determine the applicability of the findings to other contexts. In this study, transferability is considered in relation to the single case, context-specific design, focusing on early childhood computational thinking using programmable robotics kits (PRK) within an Irish ECEC setting. As such, the findings are not intended to be generalisable, instead they offer a descriptive account of the context and a working hypothesis regarding facilitating conditions that support educators in designing learning experiences to foster children computational thinking. This aligns with Merriam's (2009) view that case study, through its inductive and context-embedded nature, can generate hypotheses and insights transferable to similar settings. To further support transferability, thick description is provided in Chapter 4, Sections 4.1, 4.2, 4.3, where data excerpts from interviews, observations, field notes, and researcher reflections were integrated and presented as learning stories. These provide rich, contextualised accounts of practice, enabling readers to assess the relevance of the findings to their own contexts. However, given the specificity of the time, place, and context, the extent to which findings can be applied to other settings may vary.

### *3.8.3 Dependability*

Dependability relates to the consistency and stability of the research process, over time (Lincoln & Guba, 1985). In qualitative research, and particularly within design-based research, achieving consistency must be understood in relation to the evolving and context-sensitive nature of the co-design intervention. This research was conducted as a small-scale qualitative case within a single setting, involving two educators and eleven children. As

such, the study was shaped by its unique context, participants, and the iterative, design-led changes that occurred throughout the research process. These factors mean that the study is not intended to be directly replicable in a quantitative sense; rather, variations would be expected if the study were conducted in a different setting or with different participants. In acknowledging the contextual and the dynamic nature of this design-based research, dependability was demonstrated through the quality of the data collection and analysis along with providing a clear and detailed account of all stages of the research process (Merriam, 2009). Supporting documentation, including transcript excerpts, examples of coding and theme development, and thematic maps, are presented within Chapter 3, Section 3.6, and Appendix G, H, I, J, K. This documentation forms an audit trail (Merriam, 2009) that enables readers to follow how data were generated, analysed, and interpreted, thereby also contributing to confirmability.

### *3.8.4 Confirmability*

Confirmability refers to the extent to which the findings are grounded in the data and are a fair representation of the educators and children's participation rather than shaped solely by researcher bias, assumptions and motivations. This study acknowledges that my positionality influenced both data generation and interpretation. My insider access to the setting and role as researcher-mentor shaped relationships, interactions, and the co-construction of meaning. Confirmability was established through the development of an audit trail that documents the progression from raw data to data reduction, analysis, and reconstruction (Lincoln and Guba, 1985). The research process was further strengthened through researcher reflexivity, supported by my use of a research journal and use of the, 'What, So What? Now What?', reflective model (Rolfe et al, 2001). This journal documented decisions, reflections, and emerging insights, thereby providing an additional layer of transparency and contributing to the triangulation of data sources. These practices helped to demonstrate how my interpretations were developed and grounded in the data.

## 3.9 Summary

This chapter outlined the methodological framework for the study. Working within an interpretivist, constructionist paradigm, it adopted a Design-Based Research (DBR) approach and qualitative case study design to explore how early childhood educators co-designed and enacted play-based experiences to support young children's computational thinking (CT) with programmable robotics kits (PRK). The chapter described the co-design intervention and DBR cycles of planning, implementation, reflection and redesign within the everyday realities of the early childhood education and care (ECEC) setting.

A qualitative multimethod strategy was presented, including semi-structured interviews, planning and debrief meetings, structured child observations and participant observations with a researcher field journal. These multiple data sources were used to build a rich, contextualised picture of educators' professional learning and children's CT engagement. Ethical considerations were discussed with reference to power relations, informed consent and assent, children's rights and data protection. The chapter also outlined the use of reflexive thematic analysis (Braun and Clarke, 2006, 2019, 2021), showing how the six phases were enacted through iterative cycles of familiarisation, coding, theme development and reflexive writing.

The next chapter presents the findings of this analysis and integrates findings, analysis and discussion through the use of vignettes and learning stories, drawn from triangulated data. These are used to illustrate key themes and make children's and educators' learning visible, highlighting how the co-design process supported shifts in practice, understanding and CT-related pedagogy.

# Chapter 4: Findings, Analysis and Discussion

This chapter presents the findings of the study, together with analysis and discussion, in relation to the overarching research question:

*What are the facilitating conditions that support early childhood educators to design learning experiences that develop young children's computational thinking through purposeful play with programmable robotics kits in an Irish ECEC context?*

The findings are organised into three themes generated through reflexive thematic analysis. Each theme is supported by sub-themes which provide nuance, adding depth of meaning and drawing out subtle distinctions within the analysis, and are illustrated through extracts from the data, presented as learning stories or vignettes. These narratives are interwoven with interpretation and discussed alongside relevant research literature. Decisions regarding the inclusion of data were guided by the aims of the study, presented in Section 1.5, and the principles of qualitative case study research, prioritising depth, coherence, and analytic relevance over equal representation of participants (Yin, 2018; Braun and Clarke, 2022). Although both educators participated fully in the intervention, the data presented in the learning stories presents "compelling extracts" (Braun and Clarke, 2022, p. 133), which predominantly focus on Leah's participation. This reflects the fact that Leah's engagement more often generated detailed observable instances of pedagogical decision-making and reflection across the design-based research cycles. This difference may also be understood in light of the educators' roles within the setting, where Leah, as the lead educator, demonstrated greater confidence, likely shaped by her years of experience, and more frequently took responsibility for guiding practice and articulating pedagogical decisions. As a result, her perspectives were more readily captured within the data. In contrast, Elaine contributions were not always expressed in ways that were as readily captured through the data collection methods used. As such, Leah's contributions offered meaningful examples

of practice and insights into facilitating conditions, making this data particularly relevant for illustrating broader patterns within the themes (Braun and Clarke, 2022). Elaine's participation and contributions remained integral to the study, particularly during planning meetings and debriefs, where her questions and responses prompted Leah to elaborate on and articulate pedagogical decisions, thereby informing the analysis and my interpretation throughout, even where her contributions are less prominently represented in the illustrative learning stories. In addition, each theme is explicitly aligned with one of the sub-questions, ensuring that the findings are clearly connected to the research aims and the analysis demonstrates how the intervention addressed different aspects of the overarching research question. The three themes are interrelated and together illustrate the facilitating conditions that supported educators' professional learning in computational thinking (CT) (Figure 17).

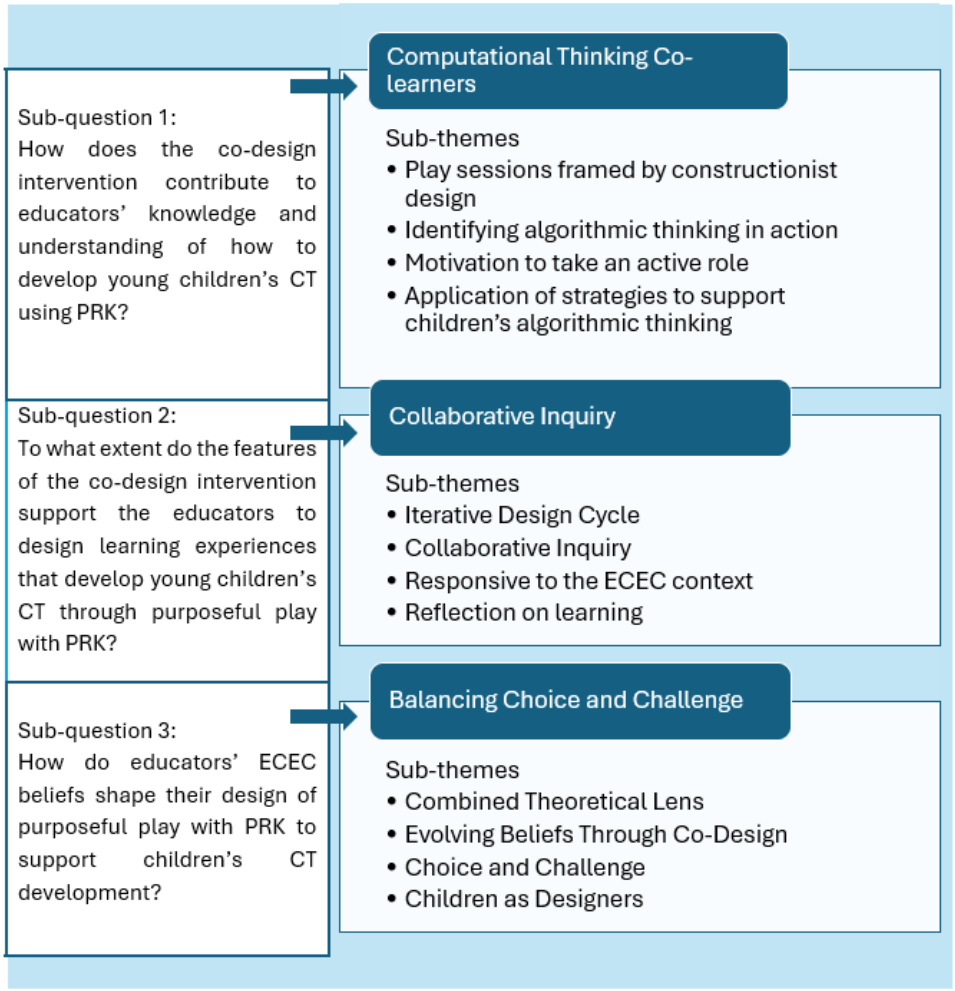



**Figure 17: Mapping Themes and Sub-themes to the Research Sub-questions**

**Theme 1: Computational Thinking Co-learners** responds to Sub-question 1, exploring how the co-design intervention contributed to the educators' knowledge and understanding of developing children's computational thinking through purposeful play with programmable robotic kits (PRK). It highlights how engaging as co-learners alongside the children enabled the educators, Leah and Elaine, to reconceptualise their role, and develop contextualised CT knowledge.

**Theme 2: Collaborative Inquiry** addresses Sub-question 2, exploring how features of the co-design intervention, including the iterative design cycle of planning meetings, play and debrief sessions supported the educators to design purposeful CT learning experiences and develop intentional pedagogy.

**Theme 3: Balancing Choice and Challenge** engages with Sub-question 3, considering how educators' ECEC beliefs shaped the design of purposeful play to foster children's CT. It illustrates how the educators worked to balance the children's choice and agency with structured challenges that fostered perseverance, problem-solving, and CT conceptual development. A summary of the themes, the sub-themes and their alignment with the sub-questions is provided in Figure 14.

## 4.1 Theme 1: Computational Thinking Co-learners

This theme addresses the sub-question: *How does the co-design intervention contribute to educators' knowledge and understanding of how to develop young children's Computational Thinking using programmable robotic kits?* The intervention provided a rich context for professional learning, as both educators, Leah and Elaine, engaged in sustained co-learning with 11 children, aged 3-5 years old, across twelve play-sessions over six weeks in their early childhood setting. The findings illustrate how the constructionist design of the intervention created iterative, in-situ opportunities for the educators to learn by doing. These opportunities supported them to reflect and refine their computational thinking (CT)

knowledge and pedagogical strategies with the children, using the programmable robotic kit (PRK), mTiny (Figure 18). The PRK became what Papert (1980) described as an "object to think with" (p.12), enabling both children and educators to engage in tangible thinking and learning about CT within a playful context.



**Figure 18: mTiny, programmable robotic kit**

By embedding professional learning within their practice, the intervention enabled the educators to learn from children's interactions, especially through moments of challenge and discovery. The findings identify that the co-learning process significantly enhanced the educators' understanding of how to develop young children's CT using PRK. Through this process, the educators developed a contextualised understanding of CT concepts such as algorithmic thinking, pattern recognition, debugging, and decomposition. The findings demonstrate how they deepened their understanding of their own role as educators, in particular scaffolding children's CT development through modelling thinking and engaging in shared thinking with the children. The process of co-learning served as a form of practitioner inquiry, enabling the educators to explore CT concepts alongside the children

through observation and guided participation resulting in them constructing valuable CT knowledge. These findings will be presented and discussed within four key areas;

- Play-sessions framed by constructionist design,
- Identifying algorithmic thinking in action,
- Motivation to take an active role, and
- Application of strategies.

### *4.1.1 Play-sessions framed by constructionist design*

Following an initial workshop which focused on developing the educators' initial CT knowledge (Appendix A), the co-design intervention model, underpinned by constructionism principles, was purposefully designed to build on this foundational CT knowledge through the 12 play-sessions. The play-sessions were designed to maximise the educators' learning opportunities, through four key constructionist principles: Learn by Doing; Object to Think With; Powerful Ideas and Reflection (Figure 19). The play-sessions provided multiple opportunities for the educators to engage in hands-on learning alongside children and the PRK, mTiny. These opportunities to learn by doing aligns with the constructionist view that knowledge is best constructed through active, practical involvement (Papert, 1980). During the play-sessions the children's thinking became the educators' 'object to think with', providing them a tangible way to understand how to support the children's development of CT (Bers, 2010). The PRK, mTiny, was intentionally chosen to facilitate the educators and children engagement with powerful CT ideas such as algorithmic thinking, pattern recognition, decomposition, and debugging (Papert, 1980; 2000). Debriefs and planning meetings following the play-sessions enabled educators to reflect on the children's thinking and their own, deepening their pedagogical understanding of how to support CT development in early childhood settings (Bers, 2010).

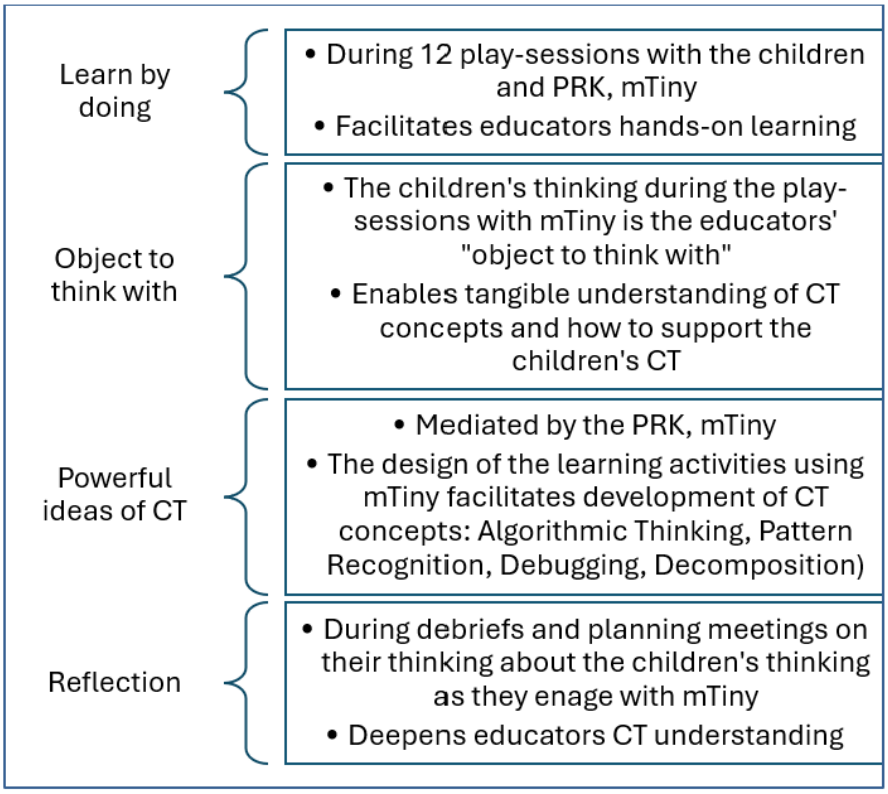



**Figure 19: The Play-sessions Constructionist Design Principles (Based on Papert, 1980, 2000, 2005; Bers 2010)**

The findings demonstrate that the underpinning constructionist principles of the play-sessions, as outlined in Figure 19, facilitated valuable co-learning opportunities with the children. These experiences contributed to the educators' knowledge and understanding of CT, as well as how to support the development of the children's CT skills. One particularly significant outcome was the unexpected shift in how the educators viewed their role by the completion of the intervention, moving from the need to be a knowledgeable guide to co-learners. As illustrated in the vignettes below, this shift challenged the educators' prior beliefs, about needing to master the PRK tools and CT concepts before introducing them to the children.

> Before starting the intervention, Leah identified that it was important to her that the initial workshop covered everything she would need to know about using the PRK, so that she would learn "… to do it right…" and could then "… do the same thing with the children" (Pre-interview). However, by the end of the intervention Leah had a different perspective, she came to value "…learning as we were going …with the children…" (Post-interview). Looking back, she reflected that both she and Elaine

> couldn't have learned what they did about CT in any other way, explaining: "We were learning with the children… [and] … also learning from them… they were teaching us… what they were learning" (Post-interview). These findings highlight how Leah's experience of co-learning during the *play-sessions* contributed to a significant shift in her belief in the value of in-situ professional learning to extend her own understanding of CT while engaging with the children's learning (Johnston et al., 2019).

Leah's changing perspective was not unique. Elaine also experienced a similar shift in her beliefs about the educator's role and the value of co-learning during the intervention.

> From the outset, Elaine felt she needed to know "… how to use them [the PRK] properly before introducing them to the children, so she would … know how to guide…" the children if they got frustrated (Pre-interview). However, when reflecting back on the 12 play-sessions, she shared how she found it "…really interesting for us all [educators and children] to learn new things… and to step back and look at them [the children] using the skills we'd learned together" (Post-interview). The value Elaine placed on learning alongside the children, in particular observing their learning through the process, suggests she is moving "…beyond the belief that they need to hold expert knowledge in all areas..." (Johnston, 2019, p.316).

Together, these vignette reflections, based on pre and post interview data, illustrate how both Leah and Elaine believed that co-learning with the children during the play-sessions provided valuable opportunities to develop their understanding of CT from the children's learning. The children's thinking as they engaged with mTiny became "objects to think with", facilitating Leah and Elaine to "think about thinking and learning about learning" (Papert, 1980, p.23) (Figure 20). The design of the intervention enabled the educators to observe the children's thinking as they engaged with the PRK during the play-sessions and to think and reflect about the children's thinking during the associated debrief sessions and planning meetings. This process supported the educators' "…development of concrete ways of thinking and learning about CT concepts and practices" (Butler and Leahy, 2021, p. 1063), which will be explored in the next sub-sections.

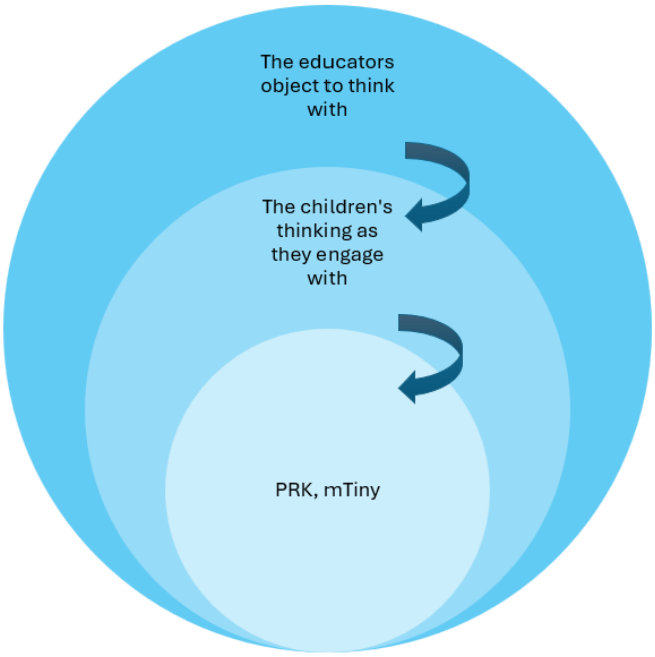



**Figure 20: The Educators' object to think with (Based on Papert 1980; Butler and Leahy, 2021)**

As the educators started with only foundational knowledge of CT concepts from the initial workshop (Appendix A), observing the children's engagement with the PRK helped to make these concepts more tangible. It enabled the educators to recognise CT concepts such as algorithmic thinking in action, interpret children's strategies, and tune into their frustrations and this contributed to the educators' understanding of both CT and the active educator role needed to develop and deepen children's CT.

### *4.1.2 Identifying Algorithmic Thinking in Action*

The findings illustrate that observing the children's thinking, about communicating the steps they want mTiny to move in, led to the educators developing new understanding of the CT concept, algorithmic thinking, and its importance as a foundational CT skill for young children. As the play-sessions progressed, the educators became increasingly attuned to the children's thinking. Leah acknowledged that, "watching them and seeing little things that they are coming up with themselves…" (Debrief 10) helped her understand how CT emerged through play. These moments offered both educators real-time, visible examples of abstract CT concepts. For instance, Play-Session 2 focused on algorithmic thinking, which is a problem-solving skill related to devising the steps needed to find a solution (Lavigne et al.

2019). During this session the children were problem solving to get mTiny to move in order to reach the bamboo shoots to eat. To do this they had to associate the correct number of steps they wanted mTiny to move on the map blocks with the coding cards they needed to tap using the controller Figure 21.

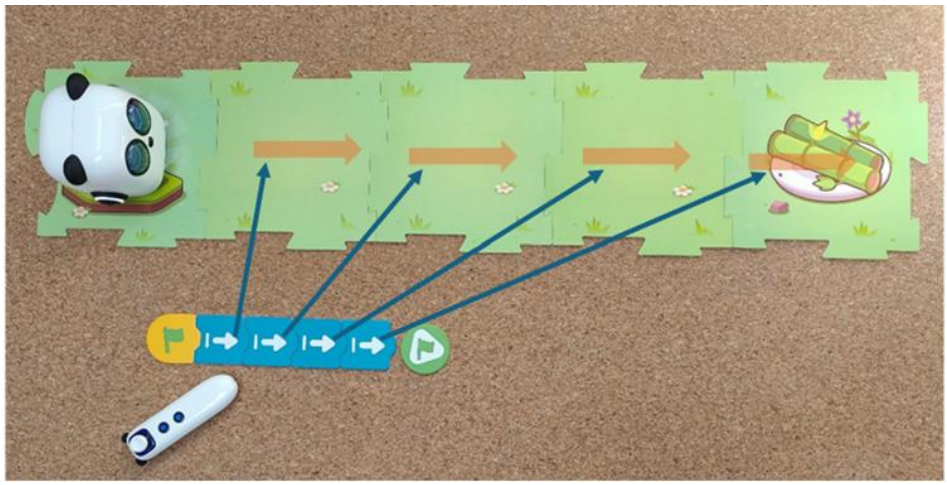


**Figure 21: Play-session 2 scenario- The steps mTiny needs to take to reach the bamboo using the blue coding cards**

The opportunities for educators to observe during the play-sessions and reflect together during the planning meetings and debrief sessions enabled them to make meaning of the children's thinking during their play with mTiny. The following story illustrates how Leah and Elaine developed their understanding of algorithmic thinking through the process of thinking about the children's thinking as they attempted to work out the steps for mTiny to reach the bamboo.

**Identifying algorithmic thinking in action**

When Leah and Elaine reflected on their observations from Play-Session 2 at the next planning meeting, they both noticed that some children showed signs of frustration when mTiny didn't move as expected after tapping the coding cards; for example, when mTiny failed to reach or moved past the bamboo.

Leah recognised it was challenging for the children "…to have to communicate to [mTiny]… through the controller…". Elaine agreed suggesting that the challenge possibly stemmed from children "…not being used to being in control…" in this way, as unlike simply pushing a toy by hand it required the children to plan steps. Through these

observations, Leah and Elaine began to connect the children's experiences to the CT concept of algorithmic thinking. To solve the problem of getting mTiny to the bamboo, the children need to identify the moves mTiny needs to make step by step. Leah observed two of the children, Charlie and Theo, beginning to do this, she noted that they had spotted that "…there's a pattern to…" the working out how many forward steps mTiny needs to take. The two children had solved how many 'move forward' coding cards were needed to get mTiny to move to the bamboo by placing each coding card in a corresponding position to each map block mTiny needed to move across (Figure 22). By placing one 'move forward' coding card against each map block, Charlie and Theo were making an association between mTiny's movements and the action the coding cards represented.

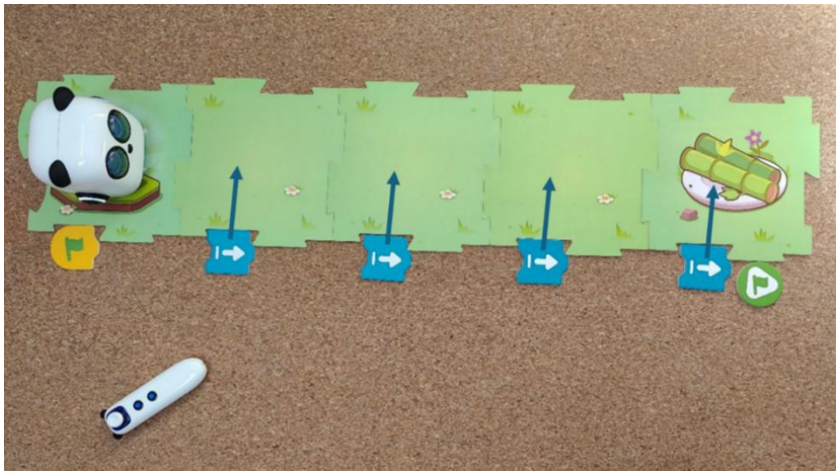


**Figure 22: Play-session 2 scenario- Charlie and Theo placed one 'move forward' coding card against each map block, making an association between mTiny's movements and the action the coding cards represented**

This example demonstrates how the children's thinking became the educators' 'object to think with' allowing Leah to personally understand algorithmic thinking 'in action' and appreciate the importance of PRKs as tangible learning tools (Papert, 2000; Butler and Leahy, 2020; Bers, 2010) (Figure 20). By tuning into the children's thinking about the pattern they had spotted (i.e. one card / one block), Leah came to understand that the children had made an association between the 'move forward' action the coding cards represented and the map blocks mTiny moved along; tapping on one coding card would move mTiny over one map block. As echoed in research by Bers (2010), the PRK provided a tangible way for the children to see and think about the association between mTiny's movements and the

coding cards, supporting their development of foundational algorithmic thinking skills. Observing the children's thinking made algorithmic thinking, the step-by-step process to solve a problem, visible to Leah. This supported her understanding of the value of algorithmic thinking as an essential CT concept that the children need to communicate the steps to the mTiny robot (Lavigne et al, 2019).

### *4.1.3 Motivation to take an active role*

Following on from Week 1, Play-Session 2, the children continued to build on the associations they made between the coding cards and mTiny's movements, provided mTiny was moving in straight lines with no turns. However, by Week 3, Play-Session 5, their interest had grown to include more complex scenarios, particularly those involving mTiny turning left and right. This added a new level of challenge, as turning required mTiny to perform two actions, move forward and then turn within a single map block (Figure 22).



The top image represents the Play-Session 5 scenario, in which mTiny takes on the 'Toby the puppy' persona and moving along the path (orange arrows) to the things Toby enjoys: playing with the ball, taking naps and chewing the bone. The inclusion of left and right turns adds increasing complexity for the children compared with Play-Session 2 (Figure 21).

The bottom image illustrates (pink arrows) how moving across one map block involves two distinct movements forward and turn. This requires the children to associate two steps, move forward and turn, with two coding cards for each map block on the path to the bone.

**Figure 23: Play-session 5 scenario involves move forward and turn**

The findings revealed that the children found it difficult to grasp that 2 cards needed to be used and also associate the correct coding cards with left and right turns. Observing these challenges prompted the educators, in particular Leah, to recognise the need to provide more support in developing the children's algorithmic thinking and understanding of directionality. Through the process of thinking and reflecting on the children's frustrations, Leah identified the core issue; the children were still developing their understanding of left and right, and they didn't yet realise that they needed to communicate this directionality to mTiny using a specific sequence of coding cards (forward-turn) for a single map block.

Leah identified that the children's challenge with directionality and associating two coding cards to a single map block was leading to frustration and impacting their perseverance and overall engagement with mTiny. This motivated her to take an active role supporting them; she recognised that her current scaffolding strategy, to stand back and provide verbal encouragement while the children explored how to determine the steps mTiny needed to take, was not sufficient. Stepping in was needed, to scaffold the children to help them make an association between the left or right turn symbols on the coding cards and the movements mTiny makes (Ackermann, 2003). As illustrated in the following learning story, tuning into the children's thinking and frustrations, around directionality, enabled Leah to craft meaningful supports (Ackermann, 2001). She engaged in strategies such as gestures, movement, and thinking aloud to bridge the gap in understanding as outlined in the following learning story.

**Leah's motivation to take an active role**

During Play-Session 5 (Figure 23), the educators and I observed the challenges the children were having with determining the steps Toby the puppy needed to take to get to the ball, bed and bone. For instance, one of the children, Charlie,

> … enjoyed attempting to programme a sequence as part of large group, but found it hard to follow the idea of working out move forward, move left, move right… Even with lots of verbal encouragement from the educators… very little understanding… shown of the left, right, forward movements. (Researcher observation)

Although Charlie had previously been successful in associating the move forward coding cards with mTiny's movements across a straight sequence of map blocks during Play-Session 2 (Figure 22), the introduction of left and right turns in Play-Session 5 added a layer of complexity (Figure 23). Reflecting on this, Leah identified the key issue: the children's lack of "… understanding of left and right …" was a barrier to effectively communicating directional steps to mTiny using the coding cards (Debrief 5).



The lefthand image illustrates that adding left and right steps requires that an association is made between a single map block and both the 'move forward' coding card and the 'move left' (or 'move right') coding card. Both steps are necessary because mTiny must first move forward one step onto the map block and then rotate direction to make the turn before making the next 'move forward' step. Although there is only one map block, mTiny performs two movements, move forward and turn, with each movement requiring its own coding card.

This added a level of complexity for Charlie when compared with moving in straight lines, as shown in the righthand image. In this image, one map block corresponds to a single 'move forward' coding card, requiring the Charlie to only associate the map block with one forward movement. In contrast, turning required Charlie to associate the left and right direction symbols with the left and right turns mTiny makes.

**Figure 24: Comparing the complexity of the coding cards steps- turns versus straight sequences**

Leah recognised that the children were "… getting fed up really quick after the first two tries…" (Planning Meeting 4) and explained that when she had seen "…how challenging it was and… had seen some frustration…" (Planning Meeting 6) it prompted her to consider how she could resolve the issue and support the children develop this thinking. Tuning into the children's frustrations around planning the steps for mTiny using the direction coding cards gave Leah valuable insights into their thinking, as well as the motivation to adopt a more active and intentional educator role. She didn't want to see the children frustrated or discouraged and felt it would be best to 'step in' "… when they weren't getting it…", to physically demonstrate the turn using her body and to model the thinking process, "…in order for them to see this is how it's done." (Post-interview). As a result, Leah shifted her role from observer to active participant, modelling gestures, narrating her decision making, and inviting the children to contribute ideas and predictions.

Leah took an active role during the children's engagement in the mTiny scenario by stepping in to support the children's thinking about which direction mTiny needed to turn. She began by demonstrating her own thought process, narrating how she decided whether the next coding card should be 'move forward', 'move left' or 'move right'. Using gestures with her arms, Leah physically indicated the direction, saying "this way" while gesturing left, and "that way" while gesturing right (Figure 25). This use of body movements to represent direction embodies body-syntonic learning, where the children relate the abstract concepts of left and right turns to their own bodily experience of turning in different directions. This approach, grounded in Papert's (1980) constructionist theory, helps the children internalise algorithmic thinking, by aligning the physical actions and spatial awareness.



**Figure 25: Play-session 5-Leah engages in body syntonic using arm gestures to relate to mTiny's movements**

Leah then connected these physical gestures to the corresponding coding cards, 'move left', 'move forward' and 'move right'. She verbally narrated her prediction, tapped the coding card, and invited the children to see whether she was correct. She then encouraged the children to investigate and discover for themselves:

> …by tapping either card as mTiny moved along the path…" to see what the outcome would be. "As each child tapped, Leah would say what was happening and ask the next question or give the prompts. She did an amazing job at simplifying a complex task and… is developing her CT by doing this". She developed her "…own strategies to make the CT concepts more real and understandable to the children" and in the process "… supporting the children is her tool for thinking about these powerful ideas [CT concepts]. (Researcher Journal)

This learning story demonstrates how Leah identified the key issue; the children needed support communicating sequences of instructions for mTiny to move to different points on the map and stepped in to resolve it. As echoed by the study findings of Kotsopoulos et al. (2021), this moment reflects Leah's developing confidence in her understanding of algorithmic thinking; not only recognising the issue but actively supporting the children. As Leah's confidence increased, her role evolved from that of an observer to one of guided participant, intentionally supporting children through modelling and shared thinking (Rogoff, 2001; 2003). This echoes Ackermann's (2003) research on pedagogical positioning which emphasises the educator's role in knowing when to step back to foster discovery and when to step in to guide deeper understanding and engagement. Leah assumed a more active role, positioning herself within the play to model thinking (Butler, 2007). Up until this point, Leah had primarily focused on observing the children's play with the mTiny, learning from their explorations. Now, by entering into the play and modelling the thinking process, she could share her own understanding to support the children's developing algorithmic thinking, a core component of CT (Ackermann, 2001; Butler and Leahy, 2021). Combining

her early childhood education and care (ECEC) expertise with her developing knowledge of algorithmic thinking enabled Leah to provide responsive, in-the-moment support. This helped to address the children's frustration while encouraging persistence and deeper engagement (Ackermann, 2003; Glezou, 2020).

As illustrated in these learning moments during Play-Session 5, Leah's knowledge of how to support children's CT grew through active participation in their interactions with mTiny. Her use of embodied, body-syntonic gestures, along with verbal explanation, supported the children to relate physical movement to the coding process, making abstract directions more concrete (Papert, 1980). Body-syntonic learning, as described by Papert, refers to the way learners use their own bodily experience to make sense of abstract concepts. In this context, Leah's physical gesture, such as using her arms to represent directional movement enabled the children to physically feel and observe the direction mTiny would take. By guiding the children to associate her arm movements with the appropriate coding cards, Leah helped them connect action, symbol, and outcome, mirroring Bruner's (1966) enactive and iconic modes of representation. Leah's gestures helped bridge the enactive and symbolic modes, encouraging the children to watch and act out the arm gesture before connecting that action to a symbolic coding card.

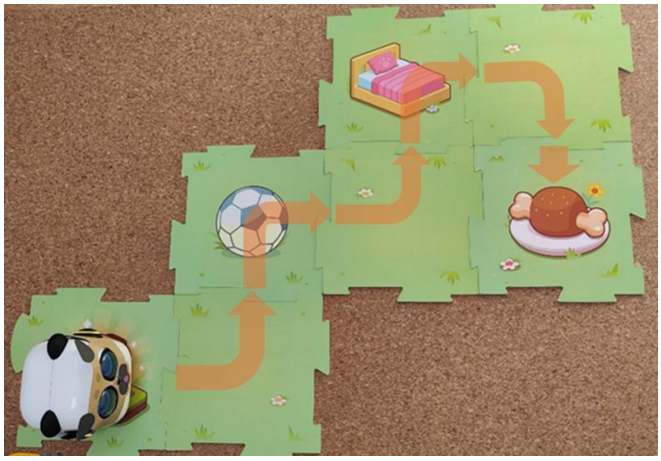
Leah encouraged trial and error, invited children to make predictions, and responded to their ideas to help them identify the next step in a sequence, which aligns with Lavigne et al.'s (2019) research on fostering young children's algorithmic thinking. Mistakes became part of an iterative learning process, shifting the focus from 'getting it right' to reasoning and debugging (Papert, 1980). Through narration and physical modelling, Leah supported the children in making connections between movement, symbol, and intention. She offered prompts, narrated actions, and made CT thinking visible, encouraging planning, prediction, and problem-solving (NCCA, 2024; French and McKenna, 2022). The modelling, narrating and questioning strategies helped make CT concepts more accessible to the children while

also supporting Leah in internalising algorithmic thinking principles herself (Butler and Leahy, 2021). By positioning herself as a co-learner, Leah engaged in situated professional learning that deepened her CT knowledge and pedagogical confidence (Ackermann, 2001).

### *4.1.4 Application of Strategies to Support Children's Algorithmic Thinking*

The findings indicate that Leah applied the understanding gained, from stepping in to scaffold the children's thinking, during Play-Session 5, to develop new strategies to further enable the children's development of algorithmic thinking during Play-Session 6. The strategies used reflect Leah's confident engagement with two core computational thinking (CT) competences: decomposition, breaking complex tasks into smaller steps, and pattern recognition, identifying common patterns in problem solving tasks (Angeli et al, 2016). In preparation for Play-Session 6, Leah redesigned the map block design used in Play-Session 5, simplifying it to further enable the children to engage algorithmic thinking and reinforce their use of left and right turns (Figure 25).

Play-Session 5 map block design



Leah made a simple change to the original map block design from Play-Session 5. Her re-design for Play-Session 6 involved moving the map block with the bone to the top right-hand corner. This small change created a repeatable sequence: forward- left-forward-right, which can be repeated three times, to the ball, to the bed and to the bone.

Play-Session 6 map block re-design



**Figure 26: Re-design of play-session 5 map blocks- one small change creates a repeatable sequence**

As illustrated in the following learning story, Leah demonstrated her growing understanding of computational thinking by redesigning the map block sequence to include a repeating pattern of steps for mTiny. Through this process, she engaged in decomposition and pattern recognition, deconstructing the larger map block sequence into smaller repeating sequences, which demonstrates her developing knowledge of CT and ability to apply CT concepts to support children's learning.

**Application of decomposition and pattern recognition**

During Week 3, Play-Session 6, the focus was to continue using the previous scenario to programme mTiny using the directional commands move forward, move left, move right, and to debug when things didn't go as planned (Figure 23). Following Play-Session 5, Leah reflected that the original map block layout was too complex, especially regarding the number of turns. She observed, "it's very hard…" for the children in terms of "their understanding of left and right. I don't think they are getting it with the [coding] cards [sequences]… they were trying, but they weren't getting it." (Debrief 5). I agreed, acknowledging, "it's a big piece of thinking… putting [it] in a [code] sequence" (Debrief 5) and she hadn't anticipated the depth of learning that was required for the children to be able to determine the left and right turn sequences, when she designed it.

Leah identified that the difficulty for the children stemmed from having too many left and right turn sequences and suggested retaining the original scenario but redesign the map

block sequence to "…have something simple… [with] left's and rights and forwards…" for the next play-session (Debrief 5). She simplified the map block design by intentionally re-designing the sequence to feature a repeating, more predictable movement pattern for mTiny (Figure 27).




The re-design created a repeatable sequence, forward-left-forward-right, which can be repeated three times:

1. to the ball (Orange).
2. to the bed (Blue).
3. to the bone (Pink)

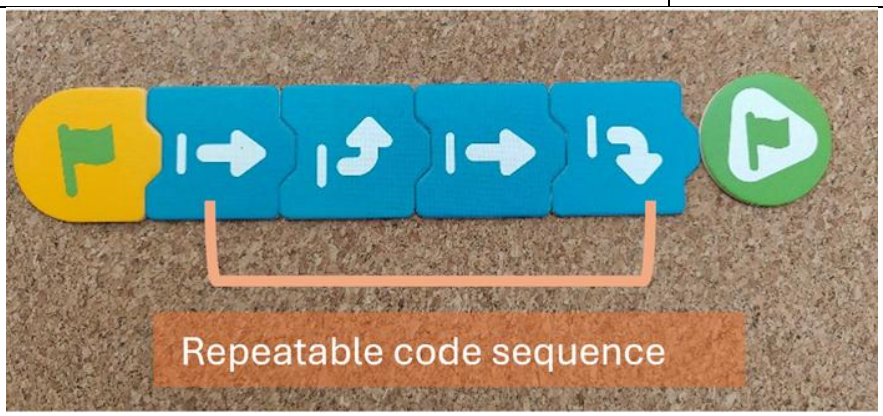



**Figure 27: Play-session 6, re-designed map block sequence and deconstructed code sequence**

This small change created a repeatable sequence, forward-left-forward-right, which could be repeated three times. In short, Leah deconstructed the code sequence, breaking it into a smaller repeating pattern of steps 'forward-left-forward-right' that would foster the children's understanding through familiarity and repetition.

The changes positively impacted the children's engagement. Elaine observed that the children were "…were more focused… [on]… using the left and right… arrows [and] more interested in getting mTiny around to the locations…" in the scenario (Debrief 6). In my role as researcher-mentor, I highlighted how the simplified sequence served as effective scaffolding, supporting the children to "…make the connection between what's on the floor [map block design], what the [coding] card is saying and what mTiny will do"

(Debrief 6). This redesign demonstrates Leah's growing knowledge and understanding of the CT concepts decomposition and pattern recognition. Leah's active role in adapting the map block design not only benefited the children's algorithmic thinking but also deepened her own understanding of CT.

As evidenced by my feedback to Leah during Planning Meeting 6:

> … you were actually engaging in computational thinking when you were supporting the children. It was quite a challenging week, because the children weren't there with their [algorithmic] thinking… you were … thinking, how do I simplify this? how do I break it into steps? So, your computational thinking was developing and… confidence with that. Whereas I felt maybe back in week one or week two, that wasn't where your thinking was… (Planning Meeting 6)

Leah was developing her "…CT through these experiences supporting the children… [she's] engaging in …pattern recognition, decomposition etc as she adapts her approach for the children" (Research Journal, Week 3).

This learning story demonstrates how observing and reflecting on the children's thinking and challenges with directionality prompted Leah to think more critically about the supports the children would benefit from. Leah applied understanding gained from observing and reflecting on the children's thinking and from positioning herself within the play to develop and refine strategies to further support the children's algorithmic thinking and directionality (Butler and Leahy, 2021). The changes made to the map design and code sequence demonstrate Leah's growing knowledge and understanding of the CT concepts decomposition and pattern recognition and the value of engaging in this thinking to break larger problems or tasks into smaller steps or patterns. When viewed through the lens of constructionism (Papert, 2000), these could be viewed as powerful ideas of CT that have become useful knowledge that Leah has internalised. Leah deepened her understanding of CT, particularly algorithmic thinking, decomposition and pattern recognition and how to effectively support the 3–5-year-olds she works with in the early childhood setting. The findings demonstrate that as a consequence of her developing this deeper understanding of CT, Leah has started to assume a new role designing and planning learning experiences to

support the children's development of CT (Butler, 2007). Leah's experience highlights the value of having opportunities to engage in professional learning within her own practice context. The co-learning served as a form of practitioner inquiry, enabling her to deepen her understanding of the educator's role (Johnston et al, 2019) in supporting the development of children's thinking and learning.

### *4.1.5 Summary*

The findings demonstrate that having the opportunity to learn alongside the children offered valuable contextual grounding that enabled the educators to apply, adapt, and contextualise new knowledge within their own practice. Overall, the co-design intervention effectively supported the educators in developing both their CT knowledge and their ability to design learning scenarios and strategies to foster CT in young children. The co-learning experience, framed as a form of practitioner inquiry, supported the educators, Leah and Elaine, to meaningfully construct CT knowledge through their engagement with the children and the PRK during the twelve play-sessions (Johnston et al, 2019). Importantly, the findings highlight the role of the children's thinking as an 'object to think with' for the educators, supporting their shift from observers to intentional facilitators of CT development for the children. The constructionist design principles of learning by doing, having meaningful objects to think with, engaging with powerful ideas, and reflecting on thinking and practice were central in transforming educators' abstract understanding of CT into embodied, pedagogically relevant knowledge. As illustrated by the learning stories the educators applied their knowledge through responsive strategies such as simplifying steps, encouraging prediction, and scaffolding problem-solving through shared thinking and actions. The educators constructed their own CT knowledge and understanding, of how to support the development of young children's CT, that was directly relevant to their practice. As a result, they were better positioned to design and plan future CT learning experiences grounded in purposeful play-based approaches, which will be discussed in Theme 2. The

findings outlined above have illustrated the significant potential of a co-designed, constructionist informed intervention to support early childhood educators' professional learning in relation to early childhood computational thinking (CT) through hands-on embedded practice with programmable robotic kits (PRK).

## 4.2 Theme 2 Collaborative Inquiry

This theme addresses the research sub-question: *How do the features of the co-design intervention support educators to design learning experiences that develop young children's computational thinking through purposeful play with programmable robotic kits?*

The key finding emerging from the data is that the iterative, collaborative, and reflective nature of the co-design model as described Figure 11enabled the educators to integrate their early childhood education and care (ECEC) pedagogical knowledge with constructionist CT principles. This integration facilitated the development of CT pedagogical knowledge and supported the emergence of an intentional pedagogy as conceptualised by Fleer (2011; 2021), who argues that educators intentionally structure play to support children's conceptual development while fostering child-led exploration. The findings within this theme also reveal that intentional embedding of the sociocultural approach to learning (Rogoff, 2003) and ECEC pedagogical knowledge perspectives (Campbell-Barr, 2019) within the constructionist (Papert, 1980) co-design framework contributed to the development of the educators' intentional pedagogy (Table 16).

**Table 16: Intentional Embedding of Theoretical Perspectives Fosters Emergence of Intentional Pedagogy**

| Constructionist (Papert, 1980) | Sociocultural Approach to learning (Rogoff, 2003) | ECEC pedagogical knowledge (Campbell-Barr, 2019) | Emergence of Intentional pedagogy (Fleer, 2011; 2021, NCCA, 2024) |
|---|---|---|---|
| Designing purposeful play and intentional learning goals to support CT: Purposeful play and iterative process with PRK makes CT visible and supports algorithmic thinking, debugging, and pattern recognition. | Collaborative inquiry between researcher (mentor) and educators (peers) situated in practice. | Co-designed purposeful play responsive to ECEC curriculum: based on children's current understanding of shapes. | CT concepts embedded in playful programming of PRK to draw geometric shapes (e.g., squares, rectangles).<br><br>Designing conceptual goals during Planning Meeting 4. |
| Educators support children's inquiry and exploration during the play-sessions.<br><br>Educators encourage children's metacognition ('thinking about thinking') during the play-sessions. | Educators engage in guided participation with children to extend thinking. | Educators support children's understanding and perseverance through modelling thinking and reflective dialogue.<br><br>Using sequencing as a storytelling approach: first, then'; 'what's another way to do this?' | Educators intentionally guide conceptual understanding of geometric shapes, algorithmic thinking, debugging and pattern recognition during Play-Session 7. |
| Educators reflect on their own/ children's CT learning during debriefs. Analyse what worked and use this to inform future planning. | Shared reflection and dialogue during debriefs fosters negotiated meaning. | Educators reflect on children's learning to support their needs. | Educators reflect on learning during the play: evident through problem solving strategies and after the play during Debrief 7. |

This theme is organised into four interrelated components that demonstrate how the features of the co-design model supported the development of CT pedagogical knowledge and emerging intentional pedagogy. First, Section 4.2.1, outlines the iterative design cycle, highlighting how the planning meetings, play-sessions, and debriefs, enabled the educators to trial, refine, and co-construct effective CT learning experiences. The subsequent three sections each address a specific step of this cycle: Section 4.2.2 focuses on collaborative inquiry, demonstrating how mentor support, peer learning, and shared problem-solving helped educators co-design and embed CT learning goals within purposeful play with PRK. Section 4.2.3 examines responsiveness to the ECEC context, illustrating how combining curriculum strategies with CT practices enhanced educators' confidence and competence to intentionally guide children's CT. Finally, Section 4.4.4 explores reflection on learning, showing how reflective cycles informed educators' design decisions for future CT experiences. Together, these four components demonstrate that the co-design model enabled educators to create intentional, play-based learning experiences that supported children's CT development.

### *4.2.1 Iterative Design Cycle*

This section outlines the iterative design cycle, a core feature of the co-design model that structured how planning, play, and reflection unfolded. As discussed in Theme 1, The co-design model was grounded in constructionist principles but was experienced by the educators through an iterative design cycle. This cycle consisted of twelve play-sessions, twelve debriefs, and six planning meetings across six weeks (Appendix B). While the model provided the framework, the iterative cycle provided educators with repeated opportunities to trial, reflect on, and refine CT-focused learning experiences in practice (Figure 28).

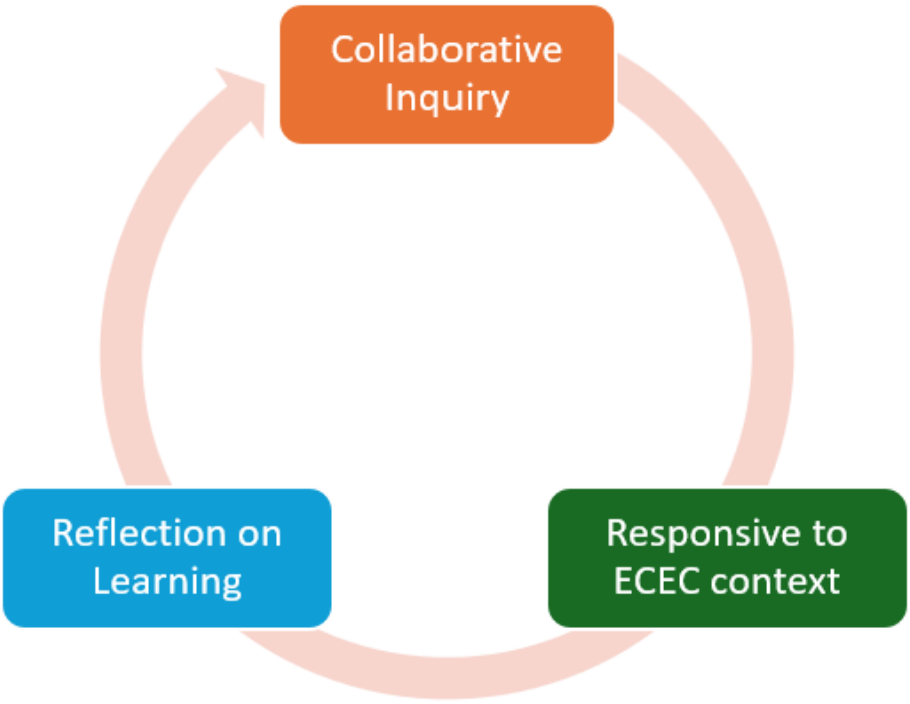



**Figure 28: Features of the Iterative Design Cycle**

The iterative design cycle offered multiple opportunities for collaborative inquiry as the educators and I planned, implemented, and reflected on the Play-Session. Across the six-week intervention, the planning meetings and post-session debriefs provided a space for the educators to co-construct pedagogical strategies and refine their approaches. From the outset, collaboration was highly valued by the experienced lead educator, Leah. She noted, "…we will all be working together on it. We will all retain different pieces of information that we have learned, so we can all collaborate together, so that is great." (Pre-Interview). By the conclusion, recent graduate, Elaine also recognised the benefits of collaborative professional learning, explaining that "… rather than one educator taking on the [co-design], working in a group together [was] much better [for] communicating …and thinking about ways that we could get this done together." (Post-Interview). Their reflections mirror findings on the value of collaborative professional learning (Barron et al., 2007; Van den Beemt and Diepstraten, 2016).

The planning meetings, held weekly, provided a structured space for collaborative inquiry. Educators drew on their ECEC knowledge of the children while integrating constructionist CT practices (Papert, 1980). This aligns with sociocultural approaches to learning (Rogoff, 2003) and ECEC pedagogical knowledge (Campbell-Barr, 2019), which emphasise designing learning that is both socially mediated and context-responsive. Both educators felt it was "very important to have those meetings…" (Elaine, Post-Interview), "so we could all plan together, so we were all on the same page…" (Leah, Post-Interview). Elaine felt strongly that both herself and Leah had valuable knowledge about the children's ECEC context based on "…observing the children this whole year…" (post-interview) and that the plans agreed needed to be based on this. This responsiveness to their ECEC curriculum context enabled the educators to create effective CT experiences for the children as discussed in Section 4.2.3. Debriefs reinforced this process by linking reflection to forward planning. Leah identified that the regular opportunities to reflect on both the children's learning and their own during the "…the Friday planning, and the debriefs… was actually helping us for…the next session. We were able to say, okay, that was not working, this was not working." (Post-Interview). These cycles strengthened both their CT understanding and their ability to design purposeful play.

The findings presented in the following sections illustrate how these features of the iterative design cycle, collaborative inquiry, responsive to ECEC context and reflection on learning (Table 17) supported educators in co-designing purposeful play with PRK within a playful learning framework. This was particularly evident in week 4, when educators collaboratively developed intentional learning goals and designed purposeful play to help the children build their understanding of CT, specifically focusing on debugging as they worked through the steps to draw a square, and will be outlined in Section 4.2.3. This process exemplified how computational thinking concepts can emerge through guided, hands-on exploration that integrates play and learning, and will be explored further in Section 4.2.3.

**Table 17: Iterative Design Cycle Fosters Intentional Pedagogy within a Playful Learning Context**

| Iterative Design Cycle | Constructionist (Papert, 1980) | Sociocultural Approach to learning (Rogoff, 2003) | ECEC pedagogical knowledge (Campbell-Barr, 2019) | Emergence of Intentional pedagogy (Fleer, 2011; 2021) |
|---|---|---|---|---|
| **Collaborative inquiry** | Designing purposeful play and intentional learning goals to support CT: Purposeful play and iterative process with PRK makes CT visible and supports algorithmic thinking, debugging, and pattern recognition. | Collaborative inquiry between researcher (mentor) and educators (peers) situated in practice. | Co-designed purposeful play responsive to ECEC curriculum: based on children's current understanding of shapes. | CT concepts embedded in playful programming of PRK to draw geometric shapes (e.g., squares, rectangles).<br><br>Designing conceptual goals during Planning Meeting 4. |
| **Responsive to the ECEC context** | Educators support children's inquiry and playful exploration during the play-sessions.<br><br>Educators encourage children's metacognition ('thinking about thinking') during the play-sessions. | Educators engage in guided participation (guided play) with children to extend thinking. | Educators support children's understanding and perseverance through modelling thinking and reflective dialogue.<br><br>Using sequencing as a storytelling approach: first, then'; 'what's another way to do this?' | Educators intentionally guide conceptual understanding, of geometric shapes, algorithmic thinking, debugging and pattern recognition, within playful learning interactions during Play -Session 7. |
| **Reflection on learning** | Educators reflect on their own/ children's CT learning during debriefs. Analyse what worked and use this to inform future planning. | Shared reflection and dialogue during debriefs fosters negotiated meaning. | Educators reflect on children's learning to support their needs. | Educators reflect on learning during the play: evident through problem solving strategies and after the play during Debrief 7. |

### *4.2.2 Collaborative Inquiry*

A key finding is that weekly planning meetings created space for collaborative inquiry, enabling the educators and I to co-design learning goals that embedded CT concepts into purposeful play with PRK, consistent with a playful learning approach that integrates child-led exploration with intentional pedagogical guidance. These meetings facilitated reflection, mentor support, peer learning, and the integration of the educators' ECEC curriculum knowledge. Planning Meeting 4 was particularly significant, not only in its focus on designing specific CT learning goals but also in the cumulative scaffolding of the previous weeks. Through repeated cycles of planning, play, and reflection, the educators had gradually built both confidence and competence. The data demonstrates that Planning Meeting 4 in particular had a significant impact on the educators confidence and competence to contribute to co-designing a set of learning goals embedding CT concepts in playful exploration of programming mTiny to draw a square shape.

Planning Meeting 4 became valuable thinking space for reviewing observations, reflecting on children's progress, and collaboratively deciding on strategies to better support the development of CT concepts such as debugging, pattern recognition, and algorithmic thinking. Importantly, these decisions were made in ways that preserved the playful, exploratory nature of the learning while incorporating more intentional scaffolding, consistent with guided play strategies. The success of this meeting was in part due to my intentionality as researcher-mentor; I had "…made it more focused, more purposeful and prepared [the educators] for it at Debrief 6" (Researcher Journal). This preparation involved providing suggestions for the next Play-Session design based on the educators' reflections during Debrief 6 with regard to the challenges the children had persevering when working out the steps for mTiny. For instance, Leah noted how one of the children, Liam, had only managed a sequence with "a couple of steps" before giving up (Debrief 6). She recognised that "if it's not working for him straightaway" he lost focus (Debrief 6). I suggested that

"…perhaps on Friday [Planning Meeting 4] we try and tease out how we encourage that persevering by drawing [with mTiny]" (Debrief 6).

As researcher-mentor, I elaborated on this idea suggesting that:

> because they're doing the shapes with you [as part of the curriculum], and they can point and say 'square', let's think about what does it mean to make a square… how can we walk around a square, we have to go straight, and we have to turn then go straight. (Debrief 6)

The educators were in agreement as they "…were already doing that at circle time", for instance, tracing shapes "in the air with their finger" (Elaine and Leah, Debrief 6). Consequently, drawing squares with mTiny became the focus for the next play-session which would be co-designed during Planning Meeting 4 with my support as researcher-mentor. I guided the educators in using the PRK to draw geometric shapes with mTiny (Figure 29), framing this as a playful, hands-on exploration that connected familiar mathematical concepts with embodied and exploratory learning using the PRK.

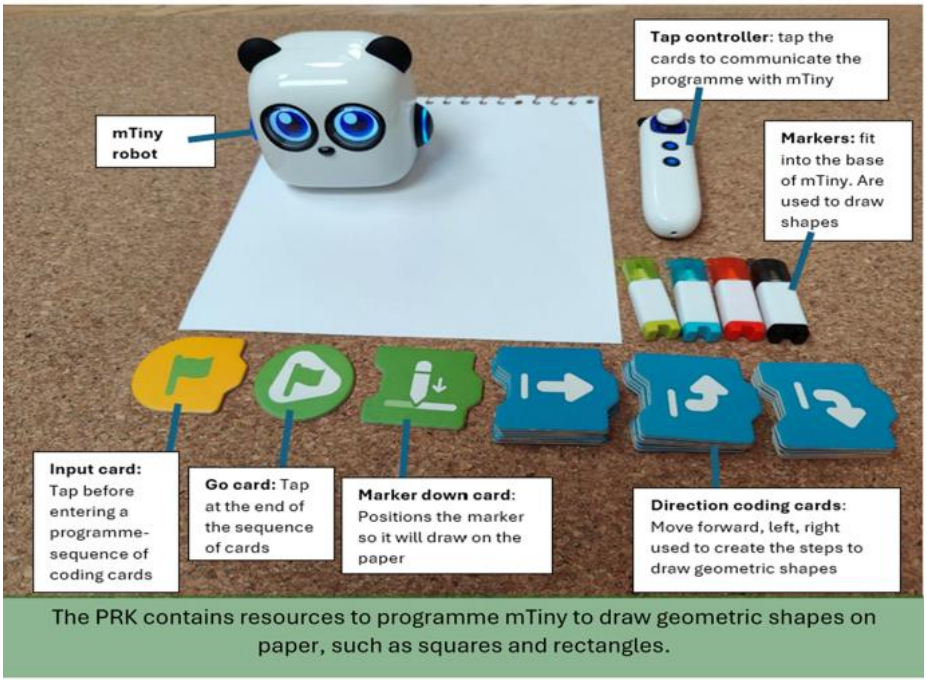



**Figure 29: The PRK resources to programme mTiny to draw a square**

Programming mTiny to draw a square offered the children the opportunity to visually assess whether the code sequence was correct (e.g., whether four equal sides were produced),

thereby making debugging more tangible (Figure 30) and fostering a playful process of trial, error, and revision.

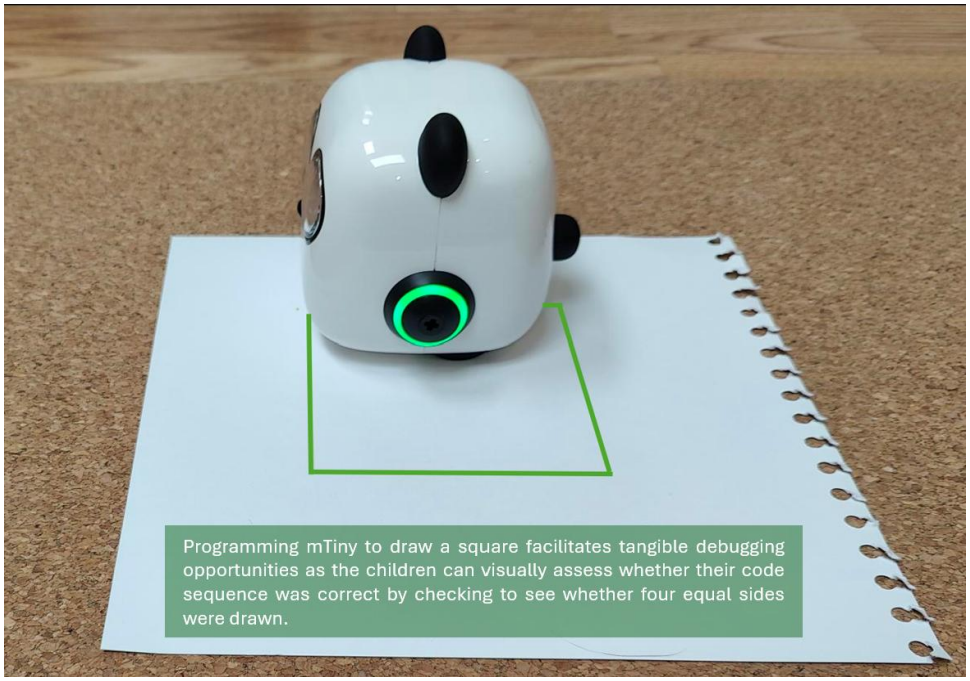



**Figure 30: Programming mTiny to draw a square facilitates tangible debugging**

Focusing on familiar early mathematics concepts in relation to geometric thinking (Van Hiele, 1986; 1999) enabled the children to apply their visual recognition of a square shape and extend their descriptive thinking by identifying key characteristics, such as having four equal sides, within a playful learning context that connected prior knowledge, embodied activity, and exploratory problem-solving.

The educators responded positively to this play-session because it aligned with their existing curriculum. Acting as researcher-mentor, I facilitated collaborative inquiry by encouraging the educators to engage in hands-on play with the PRK and experiment with sequences to program mTiny to draw a square. Linking this activity to a review of CT concepts (see Appendix Q), the educators were scaffolded to identify strategies to support children's debugging, algorithmic thinking, and pattern recognition. These strategies combined familiar ECEC practices, such as use of shape visuals, with CT strategies, for instance, building on body syntonic approaches used in Theme 1, section 4.3.4, to identify the steps

as they walk the shape of a square on the ground (Papert, 1980). The review of CT concepts and strategies strengthened the educators' contributions to planning Play-Session 7. This process resulted in the co-design of intentional learning goals that embedded CT into purposeful play, while also aligning with the ECEC curriculum and building on the children's prior understanding of squares (Appendix R). The following learning story illustrates how the planning meetings, served as a supportive, collaborative and reflective space for the educators to engage in co-designing intentional learning goals to support the children's CT through purposeful play with the PRK.

**Planning Meeting 4: Co-designing Learning Goals**

During Planning Meeting 4, I collaborative inquiry with the educators as a way to support their understanding and decision making about learning goals and pedagogical strategies for the play-session design. This involved "reviewing key CT concepts, algorithmic thinking, pattern recognition and debugging, in terms of what they are, what they look like with mTiny and how we can encourage them when coding mTiny to draw a square" (Research Journal) (Appendix Q). The educators were then encouraged to engage in hands-on exploration with mTiny "to do a bit of the coding to make a square." (Planning Meeting 4).

This assisted the educators decision making about the design of Play-Session 7 and how to support the children to achieve Learning Goal 2: *Identify a sequence of actions (move forward and move left) needed for mTiny to draw a square* (Appendix R), as illustrated below in Figure 31.

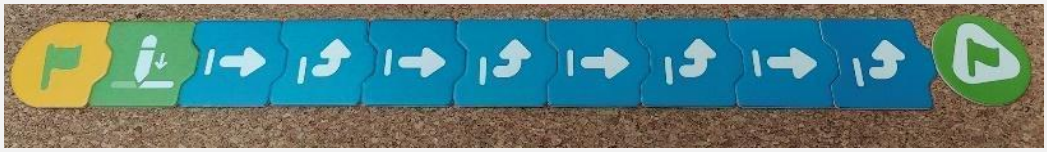
Leah verbally guided Elaine as she built the code sequence to draw a square:

**Leah**: "…you need another forward and then another left, then another forward … and another left and then you are there. I don't think they'll understand that."

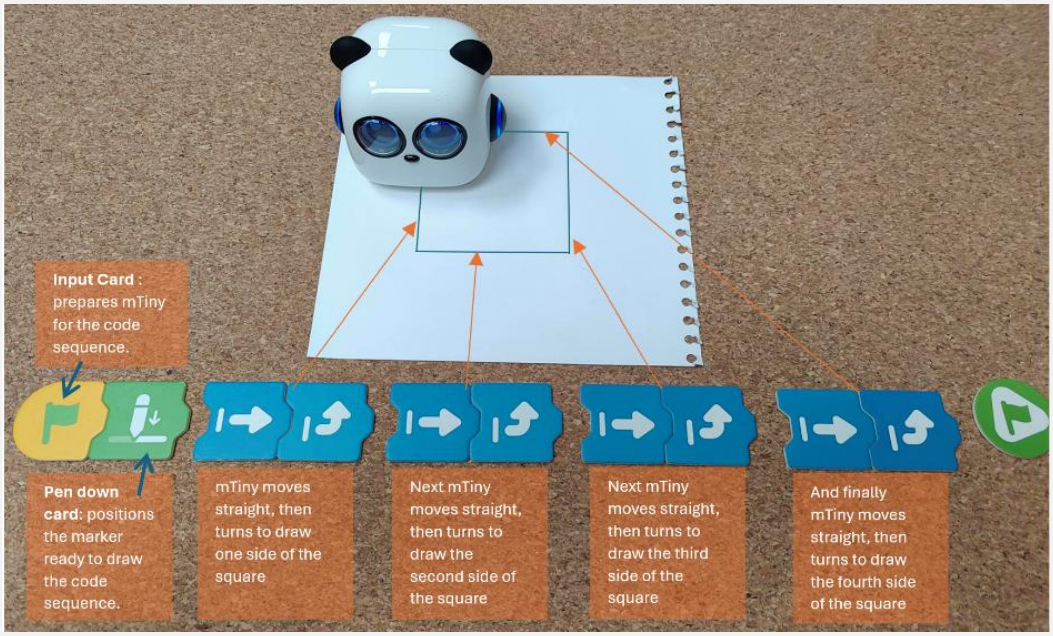
**Elaine**: "It is like a sequence though."

**Leah**: "It is like a sequence for us, we understand that."

Leah was concerned the children would find the code sequence too long, as she previously noted during Debrief 6.



On further investigation the educators identified that the sequence could be deconstructed to code one side of the square at a time.




Leah felt this was more manageable and agreed to include the deconstructed sequence in the play-session design, noting: "Yeah, I think that's a good one to start with …straight-turn… (Planning Meeting 4).



**Figure 31: Deciding on a strategy to support children to identify a sequence of steps to draw a square**

I reminded the educators this is similar to "a sequence of coding cards from a previous play-session (Play-Session 6), forward-turn, forward-turn" so we can provide verbal prompts ("do you remember when you did that the other time"), to support their pattern recognition. Leah agreed with this strategy as she has observed that the children "are remembering what they've learned and trying to bring it into what they're doing now" (Planning Meeting 7).

To further support the children to identify the forward-turn sequence of actions, Leah and Elaine suggested including activities to support visual recognition of the square shape, which were based on their ECEC curriculum context. Leah suggested that "maybe we could have shapes… [to] show them, so when you're talking about a square, they know

what you are talking about… and then they draw them in the air", Elaine agreed with having "a visual "(Planning Meeting 4). I confirmed their decisions and in addition suggested to encourage the children's ability to describe a square by encouraging them to engage in body syntonic: use their body movements to make or walk a square:

> So, we'll have a picture of the square, we will name it, 'does anybody know what this is' a square. Can we trace it with our fingers. And then have them walk it; if I get some coloured masking tape, can I map out a square here. (Planning Meeting 7)

Leah additionally suggested that "we can hold their hands and walk with them." (Planning Meeting 4).

Engaging in the review of CT concepts with me and the hands-on investigation with mTiny resulted in Leah and Elaine agreeing to and understanding the value of Learning Goals 1 and 3 (Appendix R).

LG1.*Recognise there's a connection between the instructions they give mTiny and the action it performs (drawing a square)*

LG3.*Identify errors in the sequence of actions and with support make changes and try again.*

Programming mTiny to draw a square had the potential for the children to make stronger connections between their coding sequences and mTiny's actions which would support them to recognise debugging moments.

I explained that:

> We want the children to be able to recognise there's a connection between the instructions that they give mTiny and the actions mTiny performs … to fix errors they have to spot there is an error, do you think they spot them? (Planning Meeting 4)

The educators had not observed children identifying errors with their code and acknowledged this was a challenging area especially with regard to the debugging concept. Leah noted that they "really don't get that", and Elaine agreed explaining that "they don't make the connection when somethings going wrong… they are resorting to picking up mTiny and moving it over [to where they want it to be] (Planning Meeting 4).

Through their hands-on investigation, with me guiding, the educators realised how this play-session design had potential to encourage debugging as it provided a visual output; the shape drawn or not drawn with the marker (Figure 32). In particular a connection was

made to the valuable role of the green coding card (Figure 32) with the 'marker down' symbol in supporting the children to recognise there's a connection between the instructions they give mTiny and the action it performs which helps them identify errors in the sequence of actions (Learning Goal 1 and 3) (Appendix R).



The researcher explained the purpose of the green coding card with the 'pen down' symbol "tells the marker to go down, because if you tap this [sequence] now mTiny will just do the movements and the marker won't do anything." There will be no square drawn on the paper (Planning Meeting 4).

**Figure 32: Debugging opportunities using the 'marker down' coding card**

Leah made sense of how this could support debugging thinking for the children, she clarified her thinking: "so we need the marker [coding card] … now you see, this is where the problem solving comes in" (Planning Meeting 4). I agreed clarifying further that the children "…might notice, 'oh, that didn't turn out like a square' and that might start them thinking, can we go back and try again, 'will he make a square this time? (Planning Meeting 4).

This learning story highlights how collaborative inquiry during Planning Meeting 4 supported the educators to co-design intentional learning experiences that had the potential to foster CT through purposeful play with PRK. The iterative design cycle provided time and space for the educators to reflect and revisit challenges raised in Debrief 6 on children's challenges with persevering with longer sequences of code and debugging when there were errors in the code (Stevenson et al., 2019; Butler and Leahy, 2021). The collaborative inquiry the educators engaged in aligns with Rogoff's (2003) sociocultural approach to learning,

where guided participation from me, in my role as researcher-mentor, and the dialogical shared learning supported knowledge construction in culturally and contextually meaningful ways. For instance, by connecting CT concepts to the educators' everyday curriculum practices (e.g., shape recognition, embodied play), and by valuing their prior observations about children's challenges with long code sequences. A key moment in this process occurred when the educators engaged in hands-on exploration to collaboratively investigate how to programme mTiny to draw a square and how such a task could support the children's understanding of algorithmic thinking, pattern recognition, and debugging (Papert, 1980). The experience provided an opportunity for educators to strengthen their understanding of how to use PRK to provide tangible ways to make debugging visible to the children (Heikkilä and Mannila, 2018).

The collaborative inquiry process also created a space for co-construction of computational thinking pedagogical knowledge, as the educators and I shared CT and ECEC concepts and practice (Campbell-Barr, 2019; Fleer, 2021). I introduced strategies to support children's descriptive understanding of the characteristics of a square, while the educators contributed ideas on how they currently teach visual understanding of shapes (Van Heile, 1986; 1999; Papert, 1980). Overall, engaging in collaborative inquiry during Planning Meeting 4, intentionally facilitated by me, led to the educators contributing to decisions for the design of Play-Session 7, and suggesting their own ECEC related ideas and strategies.

#### *4.2.3. Responsive to the ECEC context*

The findings indicate that combining ECEC curriculum strategies with CT practices when co-designing play-session 7 strengthened the educators' confidence and competence to intentionally guide children's CT learning. As discussed in Section 4.2.1, p. 158, being responsive to their curricular context and their knowledge of the children enabled the educators to plan and implement effective CT experiences for the children. A key factor was that, in Planning Meeting 4, the educators had first carried out the task of programming

mTiny to draw a square themselves. This hands-on experience scaffolded their own understanding and gave them the confidence to suggest ideas and strategies from their ECEC practice when co-designing the session plan. Combining ECEC and CT practices positively impacted the children's conceptual understanding of the characteristics of a square and in turn supported their algorithmic thinking, pattern recognition and debugging skills as they worked out the sequence of steps needed for mTiny to draw a square. Leah supported the children to engage with the learning goals set out in the plan for play-session 7. She encouraged the children to think about the sequence of steps needed to draw a square through inquiry and exploration where she modelled the thinking, provided demonstration and verbal prompts and encouraged the children to try for themselves. This resulted in some children achieving the learning goals and then teaching other children, as detailed in the leaning story below which demonstrates how Leah confidently implemented the play-session plan, intentionally guiding the children to engage with the learning goals by combining ECEC and CT strategies to support their conceptual understanding.

**Responsive Pedagogy: Combining ECEC and CT Practices**

"The success of Play-Session 7 was that the educators "… knew what the plan was, what their role was, how to prioritise or let go of elements, and how to adapt them." (Researcher's Journal, Week 4). Contributing to the play-session design meant that Leah confidently and competently combined ECEC and CT knowledge to support the children's understanding of CT concepts through playful exploration and inquiry based on their familiarity with the shape of a square.

During the session Leah supported a small group of three children, Ivanna, Carlos, and Liam, to create a code sequence for mTiny to draw a square. She began by modelling her thinking on which steps mTiny needed to take to draw (i.e. putting down the pen), reminding the children of when they walked the shape of a square on the floor earlier in the session. Following this "she demonstrated to the children and then stepped back to encourage them to work out the code sequence to draw one side of a square, using verbal prompts, 'which will you tap next'" (Figure 33) (Researcher Observation, Play-Session 7).

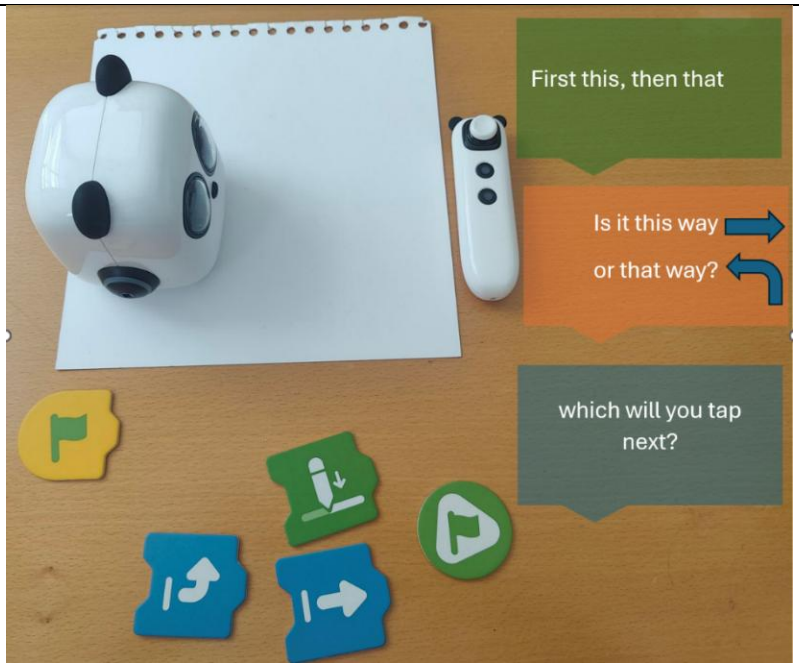



**Figure 33: Leah's Verbal Prompts to Support Sequencing Steps to Draw a Square**

To simplify the task, Leah introduced the repetitive sequence "straight–turn, straight–turn," helping the children see how repeating the same two steps would complete all four sides of a square (Figure 34). Reflecting back to the learning goals agreed on during Planning Meeting 4 (Appendix R), Leah noted that to support the children's thinking further she: "…was trying to let them work it out… letting them see that if [mTiny] goes straight and turns, then again," he will draw two sides of a square (Debrief 7). She recognised that using a repetitive, simple sequence 'straight turn- straight-turn' helped the children grasp the concept (Figure 34). This gave the children an entry point into pattern recognition, as they began to notice that the same sequence could be reapplied to achieve the overall goal.

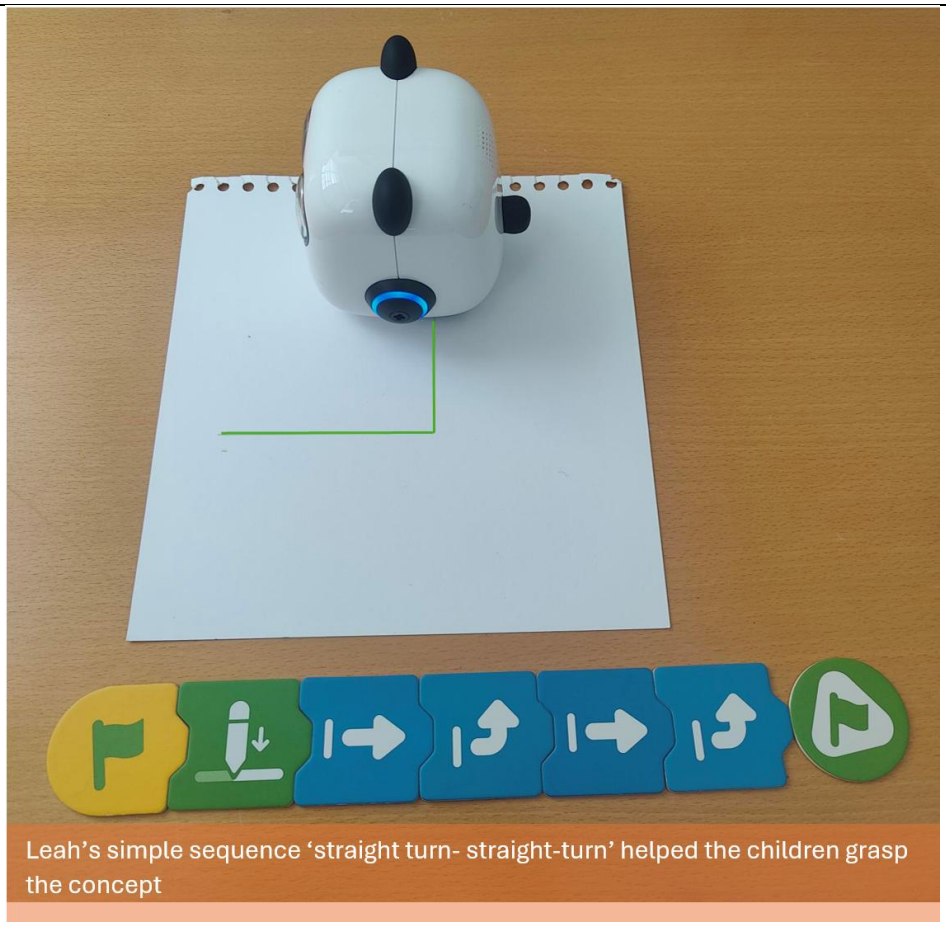



**Figure 34: Leah's single sequence helped the children grasp the concept**

Ivanna, the eldest child, quickly grasped this repeated structure. Once she recognised the pattern, she was able to apply it independently to complete the square. Leah noted that when Ivanna "got that [concept], she actually was making [the square] and showing Carlos how to do that then." (Debrief 7). Leahs implementation of these pedagogical strategies supported Ivanna's conceptual understanding of the sequence of steps to draw a square. In turn this enabled Ivanna to support Carlos by identifying errors in his code and guiding him to debug, demonstrating that not only was Ivanna developing her understanding, but was also confident to scaffold another child's understanding (Figure 35).

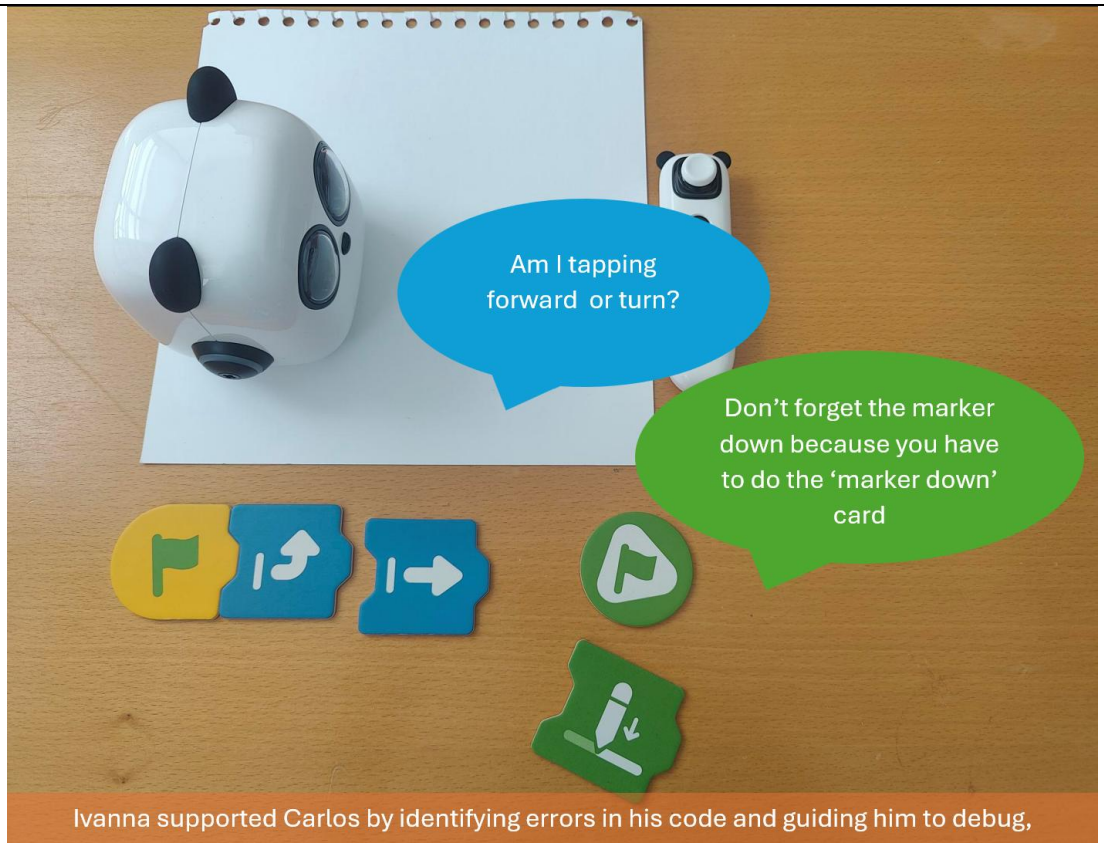



**Figure 35: Children teaching children**

Ivanna noticed the code sequence mistakes Carlos made and prompted him to spot the problems, then guiding him on how to fix them using her own system "…am I tapping forward or turn? … don't forget the 'marker down' [a coding card], because you have to do the marker down card…" to get mTiny to leave a mark on the paper (Researcher Observation, Play-Session 7).

This was an unexpected, shared learning moment when Ivanna supported Carlos to identify the sequence of steps and debug. This peer-to-peer interaction was an important moment of shared learning, illustrating how purposeful play supported children's algorithmic thinking, pattern recognition, and debugging while fostering collaboration. Leah valued that the children were getting involved with each other's ideas… [and] helping each other out" (Debrief 7) especially as it was the first time the educators and I observed this since the start of the intervention.

This learning story illustrates how the confidence developed through the iterative design cycle translated into responsive pedagogy during Play-Session 7. Leah combined ECEC curriculum strategies with CT practices to intentionally guide children's learning, supporting exploration of algorithmic thinking, debugging, and emerging pattern recognition through playful inquiry with the PRK (Papert, 1980). She confidently encouraged and extended the children's thinking through guided participation, moving between demonstrating, modelling thinking and providing verbal prompts (Rogoff, 2003; NCCA, 2024). Her ability to adapt her pedagogical role responsively, stepping in when children needed support and stepping back to encourage independent exploration, reflected her growing pedagogical intentionality. This aligns with Campbell-Barr's (2019) view that pedagogical expertise lies in knowing how children learn and adjusting strategies accordingly. It also aligns with Ackermann's (2003) emphasis on finding the right balance between 'stepping in' to support and 'stepping back' to encourage children's own discovery. For instance, Leah successfully stepped in to support Ivanna's thinking and then stepped back as Ivanna supported Carlos in how to do it, facilitating peer to peer learning to emerge. These interactions illustrate the potential for children's collaborative learning once children have developed foundational CT understanding (Rogoff, 2003; Bers, 2020).

A key factor in these successful outcomes was that the play-session design embedded CT learning goals within an ECEC curriculum area of focus, drawing a square, which provided meaningful contextual learning. This approach reflects Papert's (2000) idea that meaningful learning emerges from authentic, interest-driven projects, as well as Fleer's (2011, 2021) research on conceptual play, which emphasises the value of embedding intentional learning goals within purposeful play to foster children's conceptual understanding. Taken together, these findings suggest that Leah was beginning to develop the CT pedagogical knowledge needed to design further CT learning experiences; knowledge that was strengthened through the deliberate integration of CT goals with familiar ECEC practices. More broadly, this

supports the finding that iterative, collaborative, and context-sensitive professional learning environments enable educators to build the confidence and competence to integrate CT meaningfully into ECEC settings (Vidal-Hall et al., 2020; Glezou, 2020; Lavigne et al., 2019).

### *4.2.4 Reflection on learning*

The findings indicate that the reflective features of the iterative design cycle supported the educators with making design decisions about future CT learning experiences for the children. In particular the debriefs following each play-session enabled Leah and Elaine to engage in reflective dialogue with the me, to consider what worked, what needed adjustment, and what to prioritise in the next session. As outlined in Section 4.2.1, p. 158., these opportunities for reflection enabled the educators to make more intentional decisions about which aspects of CT to focus on, how to support them, and how to adapt activities for individual children. After co-designing and implementing Play-Session 7 (Sections 4.2.2 and 4.2.3) the educators reflected on the success during Debrief 7. Leah discussed the value of being more intentional and confident in her strategies, noting that the children were more engaged when they understood the focus of the activity. She observed that overall, the children showed greater interest in investigating with mTiny, and that the eldest child, Ivanna, was now more confident in forming and communicating code sequences. Planning Meeting 5 provided further space to reflect on Play-Session 7, where both educators noted that the children were collaborating more and applying their learning during Play-Session 8. The following learning story illustrates how reflection enabled the educators to make sense of the children's learning in Play-Session 7 and use these insights to inform the design of Play-Session 9.

**Making Learning Visible: Reflection and Forward Planning**

After Play-Session 7, the debrief created space for Leah and Elaine to reflect on the session with support from me as researcher-mentor. This reflective dialogue highlighted the value of their contributions to the intentional design of the session. Leah noted that the children's success in programming mTiny to draw a square was in part linked to her purposeful implementation of the agreed plan (Appendix R):

> the way we did it today was brilliant …taking the time to [model] what to do was more beneficial… because they [children] knew what they were learning from the start… rather than just been thrown in [to explore in their own way]. It worked really well …and they were trying to get involved (Debrief 7).

I also observed that the children "were more receptive" to working together in small groups, particularly Liam, who instead of "seeking out 'my' robot" to play with "took to the redirection…" to focus on working out the steps to move in the shape of a square. Leah agreed, noting how Liam and Ivanna "wanted their turns to… [walk the shape of] the big square [taped to the floor] and they were trying to draw it with their finger and were walking around the square… with mTiny as well…" (Debrief 7).

Through reflection, Leah recognised a marked change in Ivanna's engagement. For the first time, Ivanna was purposefully "…telling [mTiny] what to do" using a sequence of coding cards, rather than relying on trial-and-error tapping. Leah attributed this to a combination of demonstration, modelling her thinking, and then stepping back to let the children work it out through guided participation:

> … mTiny had to go in [a particular] direction… to draw the square… [modelling] definitely makes it easier for them…and then inviting the children to do it and work it out is helping their understanding (Debrief 7).

I agreed, noting that Ivanna responded particularly well to Leah's verbal guidance: "…she was able to work out what [coding card to tap] next. It was really purposeful… she knew if I tap this mTiny is going to go where I want." (Debrief 7).

Both Leah and I agreed that Ivanna's support of Carlos demonstrated her conceptual understanding of a square's characteristics and her developing algorithmic thinking, as she was able to debug his sequence independently. Ivanna recognised errors in his code without needing Leah's guidance and confidently intervened: "No, you're doing it wrong…" before showing him the correct steps (Debrief 7). I highlighted this peer

collaboration as an important learning moment that "…brings on the learning [and] thinking" (Debrief 7). Elaine later noted similar peer learning in Play-Session 8, where children built on skills that they'd learned before [in Play-Session 7] and using them again". For instance, "…they were …categorising [the coding cards], 'that will go forward' and 'that will turn,' and they knew which one to tap next" (Debrief 8).

These reflections informed decisions in Planning Meeting 5 about the next stage of learning. Elaine suggested revisiting the square activity in Play-Session 9 to consolidate learning, while Leah proposed introducing rectangles to extend the challenge: "…they know the shape of the square but with the rectangle it's different because it has the two shorter sides." (Planning Meeting 5).

This learning story illustrates how debriefs and planning meetings, facilitated by the me in my role as researcher-mentor, created valuable opportunities for the educators to reflect on both the children's learning and their own practice. For example, during Debrief 7 Leah and I discussed Ivanna's deeper engagement, her role in teaching Carlos, and which pedagogical strategies had been most effective during Play-Session 7. From Rogoff's (1990) perspective, such shared reflection between mentor and educator provided a way to interpret what happened and why it mattered for future planning. Similarly, Aistear (NCCA, 2024) describes reflective practice as "being able to interpret, understand and describe experiences, what worked well and why it worked and how it might be extended" (p.33). Campbell-Barr (2019) also emphasises that reflection on pedagogical strategies is central to professional growth in ECEC. Importantly, the educators' reflection went beyond reviewing activities; it enabled them to identify CT concepts in action. Ivanna's ability to sequence coding cards purposefully demonstrated algorithmic thinking, and her recognition of Carlos's errors showed clear evidence of debugging. Recognising these behaviours helped the educators understand how CT develops through collaboration and gave them insights into how to design future opportunities for peer learning.

Reflection also supported Leah and Elaine's emerging professional identity as CT educators. By analysing when to model, when to prompt, and when to step back, they became more

confident in navigating the balance between intentional teaching and child-led exploration. This echoes Aistear's (NCCA, 2024) framing of reflective practice as part of being an agentic educator, and Fleer's (2011) view of collaborative reflection as a core feature of intentional pedagogy. Finally, reflection during Debrief 7 and Planning Meeting 5 directly influenced the design of Play-Session 9. Elaine suggested consolidating the square activity because the children were still applying skills from Play-Session 7 in Session 8, while Leah recommended extending the challenge by introducing rectangles. This demonstrates how reflective practice acted as a bridge between analysing past experiences and co-designing future CT learning opportunities.

#### *4.2.5 Summary*

The findings from Theme 2 demonstrate that the iterative, collaborative, and reflective features of the co-design intervention were key in supporting the educators to develop pedagogical strategies that intentionally embedded computational thinking into play-based learning experiences. Through an iterative design cycle, the educators engaged in a sustained process of planning, implementing, and reflecting, which built their confidence and competence in using programmable robotic kits as pedagogical tools for CT learning. The collaborative inquiry embedded within planning meetings served as a professional learning space where the educators could combine their ECEC knowledge and context with CT concepts to co-design intentional learning goals and adapt their pedagogical strategies in response to the children's needs. Importantly, the reflective practice embedded throughout the intervention fostered a pedagogical shift from reacting to children's engagement with PRK, towards a more intentional and responsive educator role that responded to children's needs. The educators began to recognise when to model, when to step back, and how to scaffold CT concepts such as debugging, pattern recognition, and algorithmic thinking through playful, hands-on experiences. These findings highlight that sustained, collaborative, and context-responsive professional learning can enable early childhood

educators to construct CT pedagogical knowledge that combines ECEC pedagogy and CT knowledge.

## 4.3 Theme 3 Balancing Choice and Challenge

This theme addresses the research sub-question: *How do educators' ECEC beliefs shape their design of purposeful play with programmable robotic kits to support computational thinking development?*

The analysis highlights how and why the educators' beliefs about play and learning in ECEC shaped their approach to designing purposeful play with PRK to support the development of CT. The findings reveal that the educators' child-centred beliefs, prioritising choice, free play, and following children's interests, initially presented tensions when integrating intentional learning goals for CT. However, through the co-design process they began to design purposeful play strategies that balanced structure with child agency, resulting in the design of more meaningful CT learning scenarios. Their beliefs evolved to recognise the value of purposeful play that balances choice and challenge as a meaningful way to support children's CT skills and learning dispositions.

Four interrelated components structure the findings and discussion that follows. First, Section 4.3.1 presents the combined theoretical lens, drawing on Papert's (1980) constructionism and Campbell-Barr's (2019) conceptualisation of ECEC professional knowledge. This combined perspective explains how the educators' beliefs shape decisions about designing learning experiences and how children develop stronger conceptual understanding through meaningful playful projects with PRK. Second, Section 4.3.23 explores how the educators' beliefs evolved through the co-design process. Third, Section 4.3.3 analyses how the educators found an effective balance of choice and challenge, and how their views shifted toward designing learning scenarios that developed CT which were focused on children's play interests. Fourth, Section 4.3.4 identifies that when children were

given the role of designers of their own learning, for example, by creating stories for the PRK, mTiny, they were more motivated, more focused, and cared more deeply about the activity. Together, these findings offer insight into how co-design process influenced the educators' beliefs about purposeful play with PRK.

### *4.3.1 Combined Theoretical Lens*

A combined theoretical lens is used to explore how educators' ECEC beliefs influence their design of purposeful play with programmable robotic kits (PRK) to support the development of computational thinking (CT) in early childhood settings. The framework integrates Seymour Papert's (1980; 2000, 2005) theory of constructionism with Verity Campbell-Barr's (2017, 2018, 2019) conceptualisation of ECEC professional knowledge, offering insight into both how children learn and how educators' beliefs shape pedagogical decisions (Table 18).

Campbell-Barr (2019) conceptualises ECEC professional knowledge as relational, tacit, and context-dependent. According to her framework, educators' pedagogical decisions are shaped by beliefs about how children learn best. These beliefs are informed by their professional knowledge, experiences, values, and the sociocultural contexts of their practice. Such beliefs influence how the educators interpret new pedagogical tools and conceptual learning, such as PRK and CT, and whether they see them as compatible with child-led, holistic approaches to learning and development. In this study, the co-design process supported shifts in these beliefs, as the educators came to see how purposeful play with PRK could nurture both CT development and broader dispositions such as independence, perseverance, and emotional expression.

**Table 18: Combined Theoretical lens (Campbell-Barr, 2017, 2019; Papert, 1980; 2000, 2005)**

| Combined Theoretical Lens for understanding both how educators' beliefs evolve and how children learn. | |
|---|---|
| Campbell-Barr (2017; 2018, 2019): ECEC Professional Knowledge | Papert (1980, 2000, 2005): Constructionism |
| Focus: How and why educators' beliefs shape their decisions when designing purposeful play with PRK:<br><br>– Beliefs are relational, responsive, and contextually embedded.<br>– Beliefs informs decision-making about how best to support children's learning.<br>– Professional knowledge shapes how educators interpret new pedagogical tools (e.g., PRK) and whether they are compatible with child-led, holistic learning. | Focus: How and why children learn through hands-on, personally meaningful projects:<br><br>– Children develop stronger conceptual understanding through meaningful playful projects with PRK<br>– Learning by doing: children create stories and then programme mTiny to enact them.<br>– Design principles: low floor (easy entry), wide walls (multiple pathways for creativity), high ceiling (scope for progression and debugging). |
| Shared features of purposeful play with PRK (mTiny)<br>– Storytelling as a meaningful learning context<br>– Based on children's play interests and funds of knowledge<br>– Agentic: children positioned as creators, designers, problem-solvers<br>– Fosters positive learning dispositions (independence, problem-solving, perseverance)<br>– Promotes CT concepts (sequencing, debugging, algorithmic thinking)<br>– Builds knowledge through playful iteration | |

Papert's (1980) constructionism complements this perspective by positioning children as active constructors of knowledge who learn best through hands-on, meaningful projects. His emphasis on 'learning by doing' is particularly relevant in the context of PRK, where children create stories and then design the programme to enable mTiny enact the story. Constructionist learning is most effective when children are personally invested in what they create, whether that's programming mTiny to collect their favourite foods or design a city map for mTiny to explore.

The constructionist design principles of low floors, wide walls, and high ceilings (Papert, 1980; Resnick, 2017) help explain why the features of the PRK, mTiny, combined with purposeful play, foster engagement and learning. mTiny's design ensures accessibility (low

floor): the tangible coding cards and map blocks allow children to begin easily by physically placing commands in sequence, requiring no prior reading or abstract coding knowledge. This accessibility makes the PRK suitable for young children in ECEC, where learning through concrete, hands-on play is central. The open-ended design of mTiny (wide walls) supports creative exploration enabling children to create limitless stories and scenarios. They can use mTiny to act out narratives or integrate familiar curriculum topics such as shapes and journeys. These multiple pathways reflect ECEC principles of following children's interests while embedding learning goals. In addition, mTiny's offers scope for progression and challenge (high ceiling). Children can plan longer code sequences or debug errors when outcomes differ from their intentions. These challenges align with constructionist learning through iteration, while also building dispositions such as persistence and problem-solving valued in ECEC. The findings illustrate clearly that due to the combination of the design features of mTiny which closely aligned with Constructionism's principles of low floor, wide walls and high ceiling and the co-learning process the educators' beliefs evolved.

### *4.3.2 Evolving Understandings Through Co-Design with PRK*

The findings indicate that educators' early childhood education and care (ECEC) beliefs played a central role in shaping the initial design of purposeful play with PRK. They hold strong beliefs that learning should be playful, child-led and interest-driven, but also purposeful, with an emphasis on problem solving, independence and emotional regulation that prepares children for future transitions to school. These beliefs were informed by their initial teacher education, professional learning, experience in practice, and the ethos of their early childhood setting, which explicitly emphasised early intervention and holistic development. Together, these influences underpinned the educators' beliefs about how children learn best and how they should be supported (Campbell-Barr, 2019). While the educators' beliefs played a central role in initially shaping their suggestions and decisions about how the play experiences were designed, their thinking was also influenced by the

features of the mTiny PRK. The design of mTiny, coupled with constructionist principles underpinning the design of the learning scenarios enabled the children to engage in meaningful projects characterised by low floors, wide walls, and high ceilings (Papert, 1980; Resnick, 2017). Through this process the educators' developed new understanding of how purposeful play with mTiny could promote independence, problem-solving, and self-regulation. The following vignettes illustrate how the educators' professional knowledge and values (Campbell-Barr, 2019) both shaped and were reshaped by PRK's design features, contributing to evolving understandings of purposeful play.

Leah's reflections highlight the value of independence and problem-solving, while Elaine's emphasise was planning and persistence.

Leah's Evolving Understanding

It was evident from the pre-intervention interview that Leah valued dispositions such as independence and problem-solving. She explained:

> …if they want something to work, they have to be able to find a way to make it work, and if it's not working for them then they have to …think. That's really what we are about… teaching them how to problem solve (Pre-interview*)*.

Participation in the co-design process and sustained engagement with mTiny enabled her to see clearly how these dispositions can be nurtured and how she can play an active role in their development. By the final weeks of the intervention, she observed that the children were increasingly "…working independently…" and recognised that "…they had to do a lot of [thinking] in order for mTiny to be able to go where they wanted in their story… the preparation… was just as important…" (Post-interview). For Leah, mTiny's features and stories made the children's thinking visible, enabling her to see how purposeful play nurtured dispositions such as independence and problem-solving.

She came to understand that mTiny's open-ended map block design encouraged children to explore their own ideas by creating their own stories and "…working out what way… they wanted mTiny to go… and putting the sequences together, the left, right and straight…" (Post-interview). Through the open-ended design, the children's projects were characterised by "wide walls" (Resnick, 2017), with each child constructing a distinct narrative and solution for mTiny that fostered creativity and varied approaches to problem solving. Leah further recognised that hands-on, playful learning with PRK was both engaging and developmentally appropriate for introducing CT concepts in early childhood (Bers et al, 2022; French and McKenna, 2022).

She also recognised the value of programming with mTiny and its various features, observing that the children's learning was cumulative: "…they were actually putting it all together… learning as they were going… remembering what they were learning from the start…" (Post-interview). The opportunity to build progressively more complex story programmes reflects what Papert (1980) referred to as "a high ceiling", as engaging in meaningful play challenged children's thinking and deepened their understanding. Across the 12 play sessions, these iterative experiences reinforced CT concepts while nurturing positive learning dispositions (Bers et al., 2022; Glezou, 2020). These observations also align closely with Papert's (1980) claim that children construct stronger conceptual understanding when they actively create something personally meaningful.

Overall, this vignette highlights how participating in the co-design process enabled Leah to move from holding broad beliefs about fostering independence and problem-solving, to being able to articulate how mTiny's features supported these dispositions. Through this evolving understanding, she recognised that purposeful play with PRK is not only compatible with ECEC values, but also enhances children's independence, inquiry, and

problem-solving through hands-on, meaningful engagement within a constructionist learning environment. While Leah's vignette centres on independence and problem-solving, the following vignette focuses on Elaine, whose reflections highlight complementary dispositions of planning, persistence and reflective decision-making.

Elaine's Evolving Understanding

Before the intervention, Elaine emphasised the value of fostering children's patience, planning, and decision-making so they could experience "a sense of achievement when they get something the way they want…" (Pre-interview).

Her beliefs were shaped by her recent degree-level teacher education, where she had opportunities as a student to work with a similar PRK, the Bee-Bot, a simple floor robot programmed with arrow commands. Seeing the kinds of thinking she engaged in with Bee-Bot, she anticipated that the mTiny PRK could strengthen children's capacity for advance planning and self-regulation. She believes it would help with children's impulsivity in particular: "…they don't think before they make a decision… [this] …would help them to analyse… before they press the button for it [mTiny] to go…" (Pre-interview). She also expected that mTiny would encourage persistence and resilience: "…focusing on something and not giving up, trying to meet their goal and keep at it… until they get it" (Pre-interview). These expectations aligned with Papert's (1980) constructionist principles of learning through meaningful projects that involve trial and error, reflection, and creative problem-solving.

Elaine also stressed the importance of connecting PRK activities to children's play interests, believing this would increase motivation and openness to learning as the children would be "…more engaged and more open to learning new skills…" (Pre-interview). This emphasis on interest-driven learning aligns with how the PRK's

design offers 'wide walls' (Resnick, 2017), enabling learners pursue a creative, personally meaningful pathway, such as building roads or helping mTiny go on a journey. For instance, in the learning story presented in Section 4.3.4, Ivanna creates a journey for mTiny to celebrate a birthday, visit a fairground, and meet a clown.

During the intervention, Elaine's observations confirmed and extended these beliefs. She valued mTiny's interactive features, its sounds, facial expressions and emotional reactions, which immediately captured children's interest, it was "…something brand new, interactive… within the child's interests…" (Post-interview). Combined with its tangible map blocks, coding cards and tap pen controller, the activities afforded by mTiny are characterised by a "low floor" (Papert, 1980), enabling children with no prior coding experience to begin exploring intuitively by arranging blocks, tapping cards, and observing immediate responses.

As the sessions progressed, Elaine observed children developing more independent and critical thinking (NCCA, 2024): "…they were learning to think for themselves…" and to plan what "…they want to achieve…". By the end, she highlighted their significant learning gains: "When we were finished… they knew what each piece did…", a marked progression for children with no prior coding experience (Post-interview). For Elaine, these developments illustrated that the activities afforded by mTiny were characterised by a "high ceiling" (Papert, 1980). The robot's capacity for increasingly complex programming meant that children could move beyond simple commands to create longer sequences, debug errors, and engage in more sophisticated problem-solving. Consequently, children were enabled to extend their thinking and sustain challenge over time, supporting deeper conceptual understanding as well as perseverance and resilience.

> Through these experiences, Elaine was able to articulate how mTiny's features fostered the dispositions she valued, persistence, planning, and reflective decision-making. The purposeful play she co-designed built on children's interests, fostered independence, decision-making, and problem-solving through meaningful projects (Fleer et al., 2021; NCCA, 2015). This vignette therefore illustrates how constructionist design principles can be successfully enacted in early childhood contexts when mediated by educators' professional knowledge and beliefs.

Together, these vignette reflections, based on pre- and post-interview data, illustrate how both educators' ECEC beliefs shaped what they perceived as valuable learning for children and influenced their evolving understanding on the potential of purposeful play with PRK to support learning (Vidal-Hall et al., 2016). Leah's emphasis on independence and problem-solving, and Elaine's focus on planning and persistence, were affirmed and extended as they observed children engaging in personally meaningful projects with PRK. They recognised that purposeful play with PRK fostered dispositions such as perseverance, reflection, and creative problem-solving, dispositions essential for both computational thinking (CT) and holistic development (French and McKenna, 2022).

***Summary***

Their contributions reflected their relational, context-dependent professional knowledge of children's practices and settings (Campbell-Barr, 2019). When combined with constructionist learning context in which mTiny is used (Papert, 1980), this knowledge allowed them to reframe purposeful play as both consistent with and extending their existing pedagogical practices. This evolution in beliefs laid the foundation for the next stage of learning, where the educators explored how to balance children's autonomy and interests with structured opportunities for CT development, which will be discussed in Section 4.3.3.

### *4.3.3 Choice and Challenge*

Building on the shift in beliefs outlined in Section 4.3.2, the finding suggests that that when the educators combined their child-centred values (Campbell-Barr, 2019) with the constructionist affordances of the PRK (Papert, 1980), they balanced children's choice with structured CT challenges, fostering both engagement and perseverance. PRK, mTiny's, design features embodied Papert's (1980) principles of low floor, wide walls, and high ceiling which acted as a key driver for this pedagogical shift. The design of Play-Session 8 (Appendix S) reflected a shift in the educators' beliefs about following children's play interests and prioritising free play. They initially prioritised free play and exploration and were concerned that structured CT tasks might conflict with their values about how children learn best. As evidenced in the following learning story, the educators came to recognise that free play alone was not sufficient to support children's engagement with computational thinking (CT). Their observations showed that children often opted out when tasks became challenging, limiting opportunities for perseverance.

Drawing on the funds of knowledge lens outlined in Section 2.4.4, the educators began to see children's "interests" as expressions of their broader funds of knowledge (Hedges et al., 2011; Chesworth, 2016; French and McKenna, 2022). In the co-design of Play-Session 8, they intentionally used these funds of knowledge as starting points for the play session designs, inviting children to create stories for mTiny that connected with what was already meaningful and familiar to them. By mid-intervention, the educators began to see the value of integrating children's interests into purposeful play designs that provided both choice and challenge. Play-Session 8 was therefore co-designed to balance intentional CT learning goals with children's freedom to create their own stories for mTiny. This approach reflected a new alignment between ECEC values and CT learning aims, positioning children as active creators drawing on their funds of knowledge, while the educators guided them to develop skills such as sequencing, pattern recognition, and debugging.

As the following learning story illustrates, the shift from free play towards purposeful play that integrated children's interests and funds of knowledge enabled the educators to support children's creativity, persistence, and computational thinking within a playful, child-led context.

**Children's stories for mTiny offer choice and challenge**

At the beginning of the intervention, the educators strongly emphasised free play and child-led learning, reflecting their early childhood education and care (ECEC) values. They initially contributed to the purposeful play design based on their knowledge of the children's interests, favouring exploration and choice over structured CT learning goals (Researcher's Journal). For instance, during Planning Meeting 2, Leah wondered what the children "would come up with… if we left them…" to lead their own play with the PRK (Planning Meeting 2). Elaine echoed this, she was "…interested to step back and see if it wasn't structured and planned … what [the children] would come up with themselves" (Planning Meeting 2). This belief was reinforced by early observations, where children used the PRK map blocks as jigsaws or constructed imaginative cities and narratives for mTiny.

However, the educators noticed that when the children found planning the steps and sequences for mTiny to move where they wanted challenging, they tended to opt out. Elaine remarked that if given the chance for child initiated free play, they'll… opt out of the purposeful play", and Leah agreed that the children will not persevere when they find it challenging (Planning Meeting 3).

By Week 4, their thinking began to shift. They recognised that while free play encouraged creativity, it wasn't effective in building foundational CT skills. Through reflection and planning meetings, they saw the potential of integrating children's interests into more structured, purposeful play. In particular, Elaine had observed that as the children got more invested in their plans for mTiny, they developed "more patience to see what would happen… when they programmed the sequence of steps (Debrief 6). With this in mind, Elaine proposed a new approach to use "…the story, *What's mTiny doing today?*" suggesting …" that it would be better for them to create their own story, because it would get them more engaged and involved…" and this also linked "…back to Aistear" (Planning Meeting 4). Leah agreed, noting, "They're not coming up with the story

themselves… Maybe we could get them to think about… what is mTiny doing today… because they'll be thinking… where is he going and then his reactions when they get him there…" (Planning Meeting 4). These insights led to the co-design of Play-Session 8, which positioned the children as creators of their own narratives for mTiny, using the map blocks and emotion cards PRK resources. The aim of this design was to support the children's engagement and perseverance with the CT learning goals; develop sequences, recognise patterns, and to debug when things don't go as planned (Appendix S). This blend of structure and choice reflected a new balance in their practice.

Reflecting on this shift in purposeful play design, Elaine acknowledged: "It was useful having the planning meetings… so we could balance it between free play… but also have the structure where they're learning specific skills." (Post-Interview). This shift represented a change in the educators' ECEC practice and beliefs, where free play and intentional learning worked together to support meaningful and sustained engagement with CT through purposeful play.

This learning story highlights how the educators' engagement in a co-design process supported a meaningful shift in their pedagogical beliefs, specifically, a growing appreciation for the role of purposeful play with PRK in supporting children's engagement with computational thinking (CT). While the educators' original practice was strongly grounded in ECEC beliefs that prioritised child initiated free play, choice, and following children's interests, these approaches alone were not sufficient for advancing children's conceptual understanding of CT. As French and McKenna (2022) highlight, child-centred practice offers valuable opportunities for self-expression and creativity but must be balanced with pedagogical strategies that guide and extend thinking. The revised Aistear (NCCA, 2024) early childhood curriculum framework supports this position by reinforcing the importance of children having choice, challenge, and opportunities to build on their play interests. The introduction of PRK, whose constructionist design features embodied Papert's (1980) principles of 'low floors, wide walls, and high ceilings' was a catalyst for this pedagogical shift. These features made it possible for the children to create play scenarios

that began with familiar explorations, such as city-building or storytelling, and extended into CT concepts like algorithmic thinking, pattern recognition, and debugging.

The educators' evolving understanding can be framed through Campbell-Barr's (2019) work on ECEC professional knowledge, which argues that educators' beliefs about how children learn best is central to their decision-making and practice. In this study, the co-design approach enabled the educators to bring their values to the meetings and examine them critically through the iterative design cycle. The use of mTiny to develop CT within a constructionist learning environment became the focus for this collaborative reflective process. This collaborative inquiry and reflection were valuable in making their beliefs and understanding visible and, in turn, shifting their pedagogical orientation towards purposeful play and structured learning experiences grounded in children's interests while also designed with clear learning intentions. Consistent with Vidal-Hall, Flewitt, and Wyse (2020) and Barron et al. (2007) findings, the evolving of beliefs is more likely when educators collaboratively reflect on practice and observe the benefits of alternative pedagogical approaches.

### *4.3.4 Children as Designers*

The educators' purposeful play design choices positioned the children as designers of their own stories using the PRK, leading to rich, meaningful learning experiences that supported computational thinking (CT) as well as holistic learning and development. As a result, the educators developed new understandings and beliefs about the value of purposeful play with PRK. The data demonstrates that by encouraging children to design stories for the PRK, mTiny, the educators began to reframe the children's interests as valuable funds of knowledge drawn from their own lives and experiences within the preschool and at home (Hedges et al., 2011; Chesworth, 2016; French and McKenna, 2022). This shift enabled deeper engagement, as the children's stories became meaningful starting points for engaging with CT concepts such as algorithmic thinking, pattern recognition and debugging. As Elaine

noted, when the children had the freedom to create their own stories for mTiny, they became more invested and motivated to engage with challenging CT concepts. The purposeful play design effectively provided a blend of choice and challenge for the children. As the intervention progressed the educators recognised that choice fostered challenge but the children's agency as designers of their stories led to greater perseverance and deeper exploration (Appendix T). By the final week of the intervention, the educators acknowledged the benefits; the children were independently thinking, planning, and engaging in CT within meaningful story contexts. Importantly, they also recognised this approach supported broader learning dispositions such as perseverance, problem-solving and emotional expression, all of which aligned with their ECEC values (OECD, 2023; NCCA, 2024). Being able to see the success of the children designing stories for mTiny first-hand led to a shift in the educators understanding and beliefs about the value of purposeful play in supporting children's learning (Vidal-Hall, Flewitt and Wyse, 2020). As illustrated in this learning story the educators found that when the children created stories for mTiny based on their own experiences, interest or understandings, it led to more meaningful exploration which fostered their CT skills and positive learning dispositions.

**Ivanna designing, feeling, and thinking with mTiny**

During Play-Session 8, Ivanna, a five-year-old child, "was interested and confident with choosing a scenario …and setting it up" (Observation, Play-Session 8). She confidently stepped into the role of designer as she created an imaginative story for mTiny. Her scenario was intentionally planned: mTiny would celebrate a birthday, visit a fairground, and meet a clown. Using the map blocks and coding cards, Ivanna broke her story into three sequences and programmed mTiny to navigate from one event to the next: birthday cake, fairground, clown (Figure 36).




**Figure 36: Ivanna's story for mTiny**

"Ivanna tapped her [coding card] sequences to get mTiny to move from birthday cake to fairground to clown" (Observation, Play-Session 8). She confidently engaged in computational thinking as she sequenced steps of code and debugged when needed, building on understanding gained when programming a square shape, using straight-turn sequences, during Play-Session 7 (Section 4.2.3, p. 170).

But what stood out most to the educator, Leah, was how Ivanna had imagined mTiny's experience emotionally and appropriately added this to the programme sequence (Figure 37).



When she was getting mTiny to go up to the clown, she looked at the [emotions cards on the whiteboard], and said, 'we need to get the sad emoji before mTiny gets there, because he might be a bit scared and that would make him sad'. So, then we went and got it [sad emotion card] from there and she knew when to tap it in [the programme sequence] (Researcher, Planning Meeting 5).

**Figure 37: Meeting the clown- Ivanna added a sad emotion card to the code sequence**

This moment revealed the depth of Ivanna's thinking, not just computational thinking, but empathy and emotional reasoning. Leah later reflected that Ivanna's ability to anticipate how mTiny might feel based on a storyline she created was meaningful:

> …I noticed today she's able to discern times when [mTiny is] going to be sad. In her story, she planned when he gets here [Clown map block], he is going to be sad, and she was able to choose… the emoji [emotion card] for that. She knows, and I think that's very relevant… for her to recognise that when he gets here, he is going to be sad, and she was able to choose which one. (Leah, Debrief 8)

The educators recognised that by facilitating the children to design their own stories, they shared their interests as funds of knowledge, understandings and experiences from their home and preschool lives. This led to more meaningful engagement and holistic learning

and development. Leah shared Ivanna's story with her parent in relation to how Ivanna is "…in tune with emotions… which is really good... and… I told her about the clown and showed her the picture, and her Mam was really happy." (Post-interview).

> During Planning Meeting 5, the educators and I reflected on how designing their own stories for mTiny had impacted children's engagement and learning. I observed that the co-designed, story-based learning experiences with mTiny provided a more accessible and meaningful engagement with CT for Ivanna. I noted that it "has given Ivanna a chance to try thinking about it [computational thinking concepts] … in a different way," and suggested that her success deciding on the sequence of code and debugging when needed was "relieving some of that frustration" we had observed previously. Leah agreed, acknowledging the benefits of the learning experience. She added that it enabled Ivanna to "see new things, as well as [engage in] problem solving". I highlighted the meaningfulness of the learning experience: "Ivanna is able to do something purposeful, that means something to her." Leah responded simply but affirmatively: "So true.". This conversation was supported by earlier observations recorded in the researcher's journal:
>
> > The ease at which Ivanna directed her own learning, she set herself a manageable challenge and navigated her way through it, solving problems with some assistance (Research Journal 4).

This learning story illustrates how child-led, purposeful play with mTiny enabled Ivanna to engage in CT in a personally meaningful way, reducing frustration and fostering problem-solving. It also reflects the educator's growing recognition of how constructionist learning principles, particularly learning through meaningful projects, can support deeper engagement and autonomy.

The learning experience marked a turning point for the educators, both Leah and Elaine came to see that the purposeful play design encouraged not only CT but also emotional expression, empathy, perseverance, and creativity. As Elaine reflected:

> It was good that they could choose which [story]… because that got them more interested… and they had a challenge … to get into… that got them involved a lot more. And then they could expand and develop their own story … as well, so it was good for creativity and imagination. (Planning Meeting 5)

Purposeful play with PRK fostered children's exploration and creativity while also learning to plan, problem-solve, and think deeply. By positioning the children as agentic in their learning, the educators observed for themselves how playful storytelling with PRK became a meaningful experience that deepened the educators understanding of purposeful play's potential which in turn influenced their values and beliefs.

Ivanna's learning story provides an insightful example of how purposeful play with PRK, mTiny, can support both CT and holistic development in early childhood education. Her engagement in storytelling, sequencing, and emotional reasoning demonstrates how open-ended, child-led learning experiences can effectively support the development of both computational thinking and broader learning outcomes. In Play-Session 8, Ivanna confidently designed a story for mTiny involving a birthday, a fairground, and a clown, an imaginative narrative that she brought to life through sequencing and coding. Her approach to deconstructing the story into three programming steps indicated her emerging understanding of computational thinking (CT) concepts, including algorithmic thinking and pattern recognition. Importantly, Ivanna integrated emotional reasoning into her code by selecting a 'sad' emoji for mTiny in anticipation of meeting the clown. This moment revealed her growing capacity for empathy and reflective thinking, showcasing how emotional intelligence and CT can be meaningfully connected in playful learning contexts (Silvis et al., 2022; O'Sullivan and Ring, 2018).

This learning experience echoes Papert's constructionist theory, which argues that children learn most effectively when they are actively engaged in building something meaningful to them (Papert, 1980). Ivanna's story represented a personally meaningful learning experience, consistent with constructionist approaches. Her role in shaping the story for mTiny and integrating emotional elements was facilitated by the PRK and purposeful play design features which aligns with principles of wide walls and high ceilings (Papert, 1980; Resnick, 2015). The wide walls provided opportunities for creative and individualised

expression, while the high ceiling supported engagement with both emotional and computational thinking at increasing levels of complexity. The educators' reflections during and after the session further illustrate a pedagogical shift. Initially, children's interests were seen as a way to maintain engagement and reduce frustration. However, Ivanna's scenario helped educators reframe those interests as funds of knowledge, cultural, emotional, and experiential insights that enrich learning (French and McKenna, 2022; Wood and Hedges, 2016). Leah and Elaine came to recognise that supporting child-led storytelling with PRK not only cultivated CT skills but also encouraged creativity, persistence, empathy, and self-regulation, all core components of holistic development (NCCA, 2015; 2024).

#### *4.3.5 Summary*

The findings of this theme illustrate that the educators' ECEC beliefs, particularly their emphasis on child-led, interest-driven free play, significantly shaped how they approached the design of purposeful play with PRK to support CT development. Initially prioritising free play and exploration, the educators were concerned that structured CT tasks might conflict with their values about how children learn best. However, through the co-design process, including planning meetings, observations, and reflective dialogue, their beliefs began to shift. By actively engaging in the design and refinement of play-sessions, the educators began to see that CT development could be meaningfully embedded within child-centred approaches. When the children were given opportunities to create their own stories using the PRK, the educators observed increases in independence, perseverance, and problem-solving; valuable ECEC learning dispositions. Importantly, these purposeful play experiences enhanced child agency, positioning the children as designers by providing meaningful contexts for their computational thinking exploration.

This theme illustrates how educators' core ECEC beliefs (Campbell-Barr, 2019) align with constructionist strategies for supporting children's CT (Papert, 1980), and how combining

these perspectives extends professional knowledge into pedagogical approaches that are both intentional and playful. Aligning with the updated *Aistear* (NCCA, 2024) framework, the findings affirm that CT can be introduced in early childhood settings in ways that value children's interests as funds of knowledge and are respectful of children's agency. Purposeful play with PRK offers a model for such integration, bridging constructionist learning with relational, responsive early childhood pedagogy. Importantly, the educators' evolving perspectives demonstrate that intentional learning need not come at the expense of playfulness. Instead, when digital tools like PRK are used thoughtfully, they can support both conceptual learning and holistic development. Overall, this theme reinforces the potential of purposeful play to combine digital tools such as mTiny with developmentally appropriate, child-led practices.

### 4.4 Conclusion

Together, the three themes collectively address the sub-questions and illuminate the conditions that supported early childhood educators to design learning experiences that develop young children's computational thinking (CT) through purposeful play with programmable robotic kits in an Irish ECEC context. First, the findings showed that the co-design intervention significantly enhanced the educators' knowledge and understanding of how to support young children's CT through purposeful play with PRK (Sub-question 1). As co-learners, the educators developed contextualised understandings of key CT concepts such as algorithmic thinking, decomposition, and pattern recognition. Their role shifted from primarily observing children's play to actively facilitating CT-focused learning, illustrating that embedded, practice-based professional learning is a crucial enabling condition for empowering educators to design and enact CT learning experiences. Second, the iterative and collaborative structure of the co-design process emerged as a key foundation for intentional CT pedagogy (Sub-question 2). Through repeated cycles of planning meetings, play sessions, and debriefs, the educators integrated constructionist ideas with their existing

ECEC professional knowledge. This ongoing collaborative inquiry fostered their confidence, encouraged reflective practice, and provided the scaffolding needed to translate CT principles into purposeful play designs. In this way, the co-design model functioned as a framework for embedding CT in practice through cycles of investigation, reflection, and refinement. Third, the findings highlighted how the educators' ECEC beliefs shaped their design of purposeful play with PRK to support children's CT development (Sub-question 3). Their commitment to play-based, child-led learning guided them to balance children's freedom to choose with the intentional learning goals required to foster CT. Over time, they began to integrate children's interests and funds of knowledge alongside more intentional scaffolding, using these as resources to support perseverance, problem-solving, and conceptual understanding of CT. Across the co-design process, they refined how they positioned themselves pedagogically, moving between stepping back to foster agency and stepping in to provide targeted support, revealing an evolving understanding of the potential of purposeful play with PRK for CT learning. Overall, the chapter has shown that the educators' professional learning about CT, the collaborative design processes in which they engage, and their underlying ECEC beliefs are deeply interconnected. The co-design model, grounded in constructionist principles and sensitive to children's funds of knowledge, created the conditions for educators to move from observers to intentional facilitators of CT. Chapter 5 draws these findings together, highlighting their significance in relation to identifying the facilitating conditions and offers frameworks and professional learning ecology to support educators.

# Chapter 5: From Findings to Frameworks

This chapter synthesises and interprets the key findings of the study in direct response to the overarching research question:

*What are the facilitating conditions that support early childhood educators to design learning experiences that develop young children's computational thinking through purposeful play with programmable robotic kits in an Irish ECEC context?*

Drawing together the three themes presented in Chapter 4, p. 134, this discussion extrapolates how these themes each relate to a particular sub-question (Table 19) to provide a cohesive response to the research question. This is outlined in greater detail as part of Section 5.1 and Table 21 in this chapter.

***Table 19: The Three Sub-questions Mapped to the Three Themes***

| Sub-question | | Theme |
|---|---|---|
| 1 | How does the co-design intervention contribute to educators' knowledge and understanding of how to develop young children's Computational Thinking using programmable robotic kits? | Computational Thinking Co-learners |
| 2 | How do the features of the co-design intervention support educators to design learning experiences that develop young children's computational thinking through purposeful play with programmable robotic kits? | Collaborative Inquiry |
| 3 | How do educators' ECEC beliefs shape their design of purposeful play with programmable robotic kits to support computational thinking development? | Balancing Choice and Challenge |

These findings demonstrate how educators engaged with CT through purposeful play; however, further interpretation is required to explain how this learning was enabled and what conditions supported it. To move beyond description toward explanation, the findings are examined through an analytical lens that accounts for the facilitating conditions shaping professional learning. My adapted lens integrates Venkatesh et al.'s (2003) *Unified Theory of Acceptance and Use of Technology* (UTUAT) model, which identifies the determinants that influence engagement with technology, with the Department of Education's (DE, 2023)

dimensions of professional learning: knowledge (*knowing what*), skills (*knowing how*), and values (*knowing why*). This combined lens guides my interpretation of the findings and illustrates how specific facilitating conditions supported the educators to design CT learning through purposeful play with the PRK. The UTAUT Model (Venkatesh et al, 2003), presented in Figure 38 provides a useful framework for understanding how beliefs, knowledge, skills, and contextual factors influence educators' decisions to adopt new digital approaches. Originally developed to explain intention and behaviour in technology use in workplace contexts, its four constructs, *Performance Expectancy*, *Effort Expectancy*, *Social Influence*, and *Facilitating Conditions*, also offer a way to identify the specific supports educators require when engaging with new technologies.

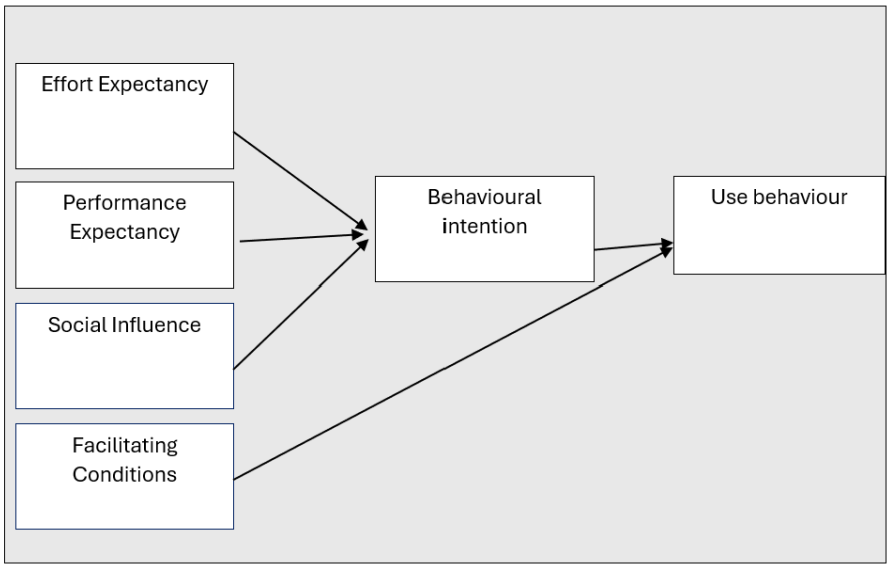



**Figure 38: UTUAT Model (Adapted from Venkatesh et al., 2003)**

In the context of these research findings the constructs have the potential to make visible the motivating factors behind the educators' decisions but also help identify the supports that enabled the development of their knowledge (*knowing what*), skills (*knowing how*), and values (*knowing why*). To apply this adapted lens meaningfully to this research context, it is necessary to move beyond the four core constructs and consider their associated sub-determinants. These sub-determinants provide a more nuanced way to interpret how each UTAUT construct aligns with the professional learning dimensions of knowing what,

knowing how, and knowing why. Table 20 presents this mapping, illustrating how the adapted UTAUT lens contextualises the educators' learning and highlights the specific supports that enabled their engagement with CT through purposeful play.

**Table 20: Adapted Lens: Mapping UTUAT to Professional Learning knowledge, illustrating how the adapted lens contextualises learning and supports in this Study**

| UTUAT Construct (Venkatesh et al., 2003) | Sub-determinant | Research Context Application | DE (2023) Professional Learning Dimension |
|---|---|---|---|
| **Effort Expectancy** | Perceived ease of use | Initial engagement with CT concepts and PRK through co-learning with children | **Knowing What** |
| | Complexity | Designing learning experiences to support CT within purposeful play | **Knowing How** |
| | Ease of Use | Implementing purposeful play with PRK to support CT development in practice | |
| **Performance Expectancy** | Perceived usefulness | Educators recognise CT through purposeful play as valuable learning | **Knowing Why** |
| | Extrinsic Motivation | Researcher-mentor encouragement supports belief in CT's value | |
| | Job-Fit | Alignment between educators role and intentional pedagogy to support children's CT development | |
| | Relative Advantage | Educators see CT fostering new ways of thinking and problem-solving | |
| | Outcome Expectations | CT through play with PRK enhances children's learning dispositions | |
| **Social Influence** | Subjective norm | Perceived expectations from researcher-mentor to engage with in designing CT learning experiences | **Supports Knowing What / How / Why** |
| | Social factors | Existing culture in the setting shapes comfort with CT and PRK | |
| | Image | Professional identity: wanting to appear confident and competent when engaging with CT and PRK | |
| **Facilitating Conditions** | Perceived behavioural control | Confidence and access to PRK resources to implement CT learning | **Supports Knowing What / How / Why** |
| | Facilitating conditions | Time, mentoring, collaboration, and pedagogical support to design CT learning experiences with the PRK | |
| | Compatibility | Fit between CT purposeful play and educators' existing values and pedagogical approaches | |

Table 20 demonstrates how the constructs of *Effort Expectancy* and *Performance Expectancy* align with the three dimensions of professional learning identified by the Department of Education (2023), *knowing what, knowing how*, and *knowing why*. These constructs trace the evolving learning in which the educators gradually moved from understanding the nature of computational thinking, to designing learning experiences, and ultimately recognising its pedagogical value within early childhood practice. However, the findings also revealed that this progression was not achieved individually but was shaped by relational and contextual supports. In this ECEC context, *Social Influence*, through mentoring, peer collaboration, and reflective dialogue, operated alongside *Facilitating Conditions* such as time, access to tools, and situated practice. These were inseparable in practice and together enabled the development of Effort Expectancy and Performance Expectancy. For this reason, the adapted lens used in this study and presented in Figure 38 merges *Social Influence* and *Facilitating Conditions,* to reflect the relational nature of professional learning in ECEC and supports required for educators to develop *knowing what*, *knowing how*, and *knowing why*.

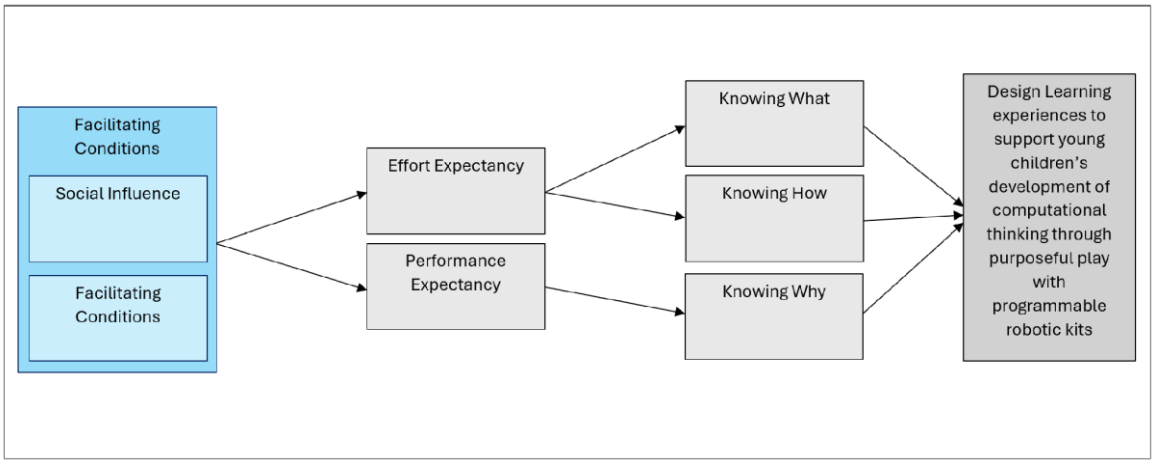



**Figure 39: Analytical Lens Developed for this Study (adapted from Venkatesh et al, 2003; DE, 2023)**

By adapting UTAUT to an ECEC context and aligning it with the DE (2023) professional learning dimensions, this chapter offers a novel analytical lens developed through the interpretive process of this study. This lens was not applied retrospectively, but constructed inductively from the data to explain how educators developed conceptual (knowing what), pedagogical (knowing how), and values-based (knowing why) understandings of CT. In particular, the findings indicated that the development of knowing how was not an individual endeavour but emerged through collaborative inquiry and iterative design processes. These processes were conceptualised in the *DISC Framework for Collaborative Inquiry in Designing CT Learning Experiences* (Section 5.1.2), which I developed from the findings to describe how educators translated emerging CT knowledge into intentional pedagogical practice. Similarly, the *SEA Framework of Structural, Experiential, and Attitudinal Supports* introduced, in Section 5.2.1, was generated through thematic synthesis to account for the structural, experiential, and attitudinal supports that enabled this learning to occur. Together, DISC and SEA form a model of professional learning, presented in Section 5.3, that has been uniquely constructed within this study and contributes a new way of conceptualising CT pedagogy in ECEC as a relational and ecological process, shaped by a broader system of relationships and contextual supports.

The following sections apply this adapted lens to the three themes from Chapter 4. Section 5.1 traces the evolution of professional learning across knowing what to knowing how (via the DISC Framework), and finally to knowing why. Section 5.2 examines the facilitating conditions that supported this progression through the SEA Framework. Section 5.3 synthesises these insights into the professional-learning ecology model, which was developed in this study and represents the key theoretical contribution arising from the findings. The DISC and SEA frameworks and the resulting model were developed specifically for this study and are offered as original contributions to understanding how CT pedagogy can be supported in ECEC contexts.

## 5.1 Mapping the Evolution of Professional Learning

This section traces how the educators' professional learning developed throughout the intervention by building on the Mapping of UTUAT to Professional Learning Knowledge presented in Table 20. The adapted analytical lens presented in Figure 39 integrates the UTAUT Model (Venkatesh et al., 2003) with the Department of Education (2023): *knowing what*, *knowing how*, and *knowing why*. dimensions of professional learning to explain how facilitating conditions shaped the educators' learning and practice. This lens reveals that professional learning did not progress in a linear way but emerged through iterative cycles of practice, reflection, and collaboration, in which understanding, application, and pedagogical purpose continually informed one another. As illustrated in Table 21 below, each theme identified in Chapter 4 aligns with one of the three dimensions of professional learning outlined by the Department of Education (2023). These professional learning dimensions provide a structure for interpreting the findings and illustrate how the educators' engagement with computational thinking developed across conceptual, pedagogical, and value-based domains. In the following subsections, each theme is interpreted through this adapted lens: Theme 1 is understood as the development of *knowing what*, Theme 2 as *knowing how*, and Theme 3 as *knowing why*. Taken together, these dimensions show how the educators moved from recognising CT in practice, to designing learning experiences, to identifying its pedagogical value within purposeful play. This interpretation forms the basis for examining the specific facilitating conditions that enabled this process, which are explored further in Section 5.2.

**Table 21: Applying the Analytical Lens to Theme Findings in this Study**

| Sub-question | Theme | Facilitating conditions within the theme | Evidence from the findings | Evolving learning within the theme | Evidence from the findings | Knowledge development |
|---|---|---|---|---|---|---|
| 1 | **Theme 1: Computational Thinking Co-learners**: | **Perceived behavioural control & Image** (confidence, access, professional identity) | – Learn by doing over time through hands-on play with the PRK and the children in their setting<br>– Exploration of the powerful ideas of CT mediated by the choice of PRK, mTiny<br>– Observation of children's thinking during their play with the PRK<br>– Ongoing reflection on their own and the children's thinking and learning | **Effort Expectancy- Perceived ease of use** — growing confidence in recognising CT through play | - Recognition of CT via children's play<br>- Shift from uncertainty to confidence | **Knowing what** young children's computational thinking involves and how it can be developed through purposeful play with programmable robotic kits. |
| 2 | **Theme 2: Collaborative Inquiry** | **Facilitating Conditions & Subjective Norm** (time, mentoring, peer collaboration, expectations) | Iterative design cycle<br>– Time to reflect and refine practice<br>– Integration of existing ECEC knowledge with CT concepts<br>– Peer collaboration and inquiry<br>– Mentoring scaffold linking CT concepts to ECEC goals | **Effort Expectancy Complexity → Ease of Use** — CT design becomes achievable | - Confidence increases over time<br>- Links made to ECEC curriculum | **Knowing how** to design and implement CT learning experiences through purposeful play with programmable robotic kits. |
| 3 | **Theme 3: Balancing Choice and Challenge** | **Compatibility-** Fit between CT, purposeful play and educators' existing values and pedagogical approaches<br>**Social factors**- Existing ECEC culture in the setting shapes comfort with CT and PRK | – Including their underpinning ECEC beliefs in the decision making process.<br>– Reflective dialogue and mentoring to support value alignment<br>– Observation of children's learning and dispositions in CT play<br>– Experiences that affirmed CT as meaningful and worthwhile within ECEC contexts. | **Performance Expectancy:**<br>• **Perceived usefulness**<br>• **Outcome expectations**<br>• **Extrinsic motivation**<br>• **Job-fit / role alignment**<br>— motivation to integrate CT | - Educators recognised CT as valuable & meaningful<br>- Observed alignment with valued dispositions (e.g. perseverance, problem-solving)<br>- Mentor support affirmed value<br>- Belief CT "fits" their role emerged | **Knowing why** developing young children's computational thinking through purposeful play with programmable robotic kits is valuable learning. |

### *5.1.1 Knowing What: Building Conceptual Understanding of Computational Thinking*

The findings from Theme 1 (Section 4.1, p. 137), map to sub-question 1 and directly respond to the research question by illustrating that co-learning opportunities framed by constructionist principles (Papert, 1980; 2000, 2005) (Figure 19), supported the educators in developing a foundational understanding of computational thinking (CT). As mapped in Table 21, this learning aligns with *Effort Expectancy* in UTAUT, where access to PRK resources, mentoring, and opportunities for exploration helped educators feel increasingly confident to engage with CT. This corresponds with the DE (2023) dimension of knowing what, as educators began to build conceptual clarity about what CT involves and how it can emerge through play.

Grounded in constructionist principles of learning-by-doing, the educators engaged in hands-on play with the PRK, mTiny, alongside the children. Acting as co-learners, they began to construct understandings of key CT concepts, such as algorithmic thinking, decomposition, and pattern recognition, within their own practice contexts. Features of mTiny supported this process: direction coding cards encouraged embodied planning and sequencing, while tapping the cards with the controller linked symbols to robot actions, promoting problem-solving. As discussed in Section 4.1.1, p.138, the educators explored how the powerful ideas of CT were mediated through the design of mTiny, they observed children's thinking as it unfolded through play and used these observations as "objects-to-think-with" (Papert, 1980, p.23), deepening their own conceptual understanding (Figure 20). Their understanding of CT moved from being a collection of abstract concepts to becoming visible tangible ideas through their interactions with the children. for example, when children planned routes, sequenced steps (algorithmic thinking), tested ideas, and revised their approaches when outcomes did not align with their intentions (debugging). These processes were articulated in situated, experiential terms, such as the children trying to think how they're going to get mTiny to move the way they wanted. The educators

acknowledged that they often observed these processes without explicitly identifying them as computational thinking, suggesting that CT was enacted in practice prior to being formally recognised or named. This highlights that knowing what CT is extended beyond acquiring terminology; it involved recognising patterns of thinking in action within their pedagogical contexts.

The post-intervention data provides insight into how the educators understood computational thinking by the end of the intervention. Table 22 presents the observed processes of CT in practice, illustrating how the educators and researcher-mentor recognised these processes in children's play, interactions and problem-solving, and how this informed their interpretation of CT in this early childhood context.

**Table 22: Educator Understanding of Early Childhood Computational Thinking**

| The educator and mentor's understanding of early childhood computational thinking post-intervention | | |
|---|---|---|
| **Observed Processes of CT in Practice** | **Post-intervention participant extracts** | **Interpretation of CT in Early Childhood** |
| **Play-based** | "for their age that's how they're going to learn…through play" (Leah) | CT is an extension of existing early childhood play-based pedagogy. |
| **Problem-solving** | The children "had to really try and sit and think how they're going to get it to work" (Leah)<br>The children were "focusing, really concentrating and practicing" (Elaine) | CT involves dispositions and ways of engaging with problems. |
| **Algorithmic Thinking [Sequencing]** | The children "were working out what way…they wanted mTiny to go" (Leah)<br>"I saw them putting the sequences together the left, right and straight, when they were trying to get [mTiny] to go certain ways" (Leah) | Children's engagement in planning and sequencing. |
| **Pattern Recognition** | The children "were remembering what they were learning from the start and…putting it all together" (Leah)<br>"I think [the children] went on a journey of discovering how these things work and how they connect" (Elaine) | Spotting patterns from before that can be reused this time. |
| **Debugging** | "if that's not working…how are we going to fix it?" (Elaine) | Finding and fixing mistakes and solving problems. |
| **Decomposition** | The educators "were the ones thinking, 'how do I simplify this?', 'How do I break it into steps?" (Researcher-mentor) | Breaking larger steps into smaller steps. |
| **Social interaction** | "we were learning with the children" (Leah)<br>The children were "learning from each other…watching their friends" (Leah)<br>"we were working together…how can we do this differently?" (Elaine) | CT is co-constructed through dialogue, modelling and shared activity. |
| **Pedagogical strategies** | "with mTiny, [the children] have a vision and they want us to help them get to their vision" (Elaine)<br>"if [the children] were struggling with something… Then we have to step in to get them to think what way they can communicate to mTiny to go the way they want him to go.' (Leah)<br>Modelling Thinking "I was doing… the thinking myself… to show them" (Leah)<br>Verbal prompts: "what about if we tried this way?" (Leah)<br>"being able to share what I've learned and step back" (Elaine) | Supporting Thinking as a pedagogical strategy for CT: Stepping in and stepping back. |
| **Tangible affordance of the PRK** | "we were actually seeing what [the children] were thinking" (Elaine) | Making the thinking processes visible. |

This evolving understanding also relates to the UTAUT sub-determinant *Image*, as educators expressed a desire to feel knowledgeable and professionally confident when engaging with CT. Through ongoing reflection on their own and the children's learning, their role began to

shift from observers to facilitators of CT learning. This research demonstrates how embedded, practice-based professional learning constituted a key facilitating condition for building educators' conceptual knowledge enabling them to move from abstract understandings of CT towards a situated, experience-informed and pedagogically meaningful interpretation. In addition to the educators, my understanding of computational thinking (CT) in early childhood evolved through my role as researcher-mentor during the co-design intervention. The interactions between children, educators, and mTiny became my own object-to-think-with (Papert, 1980), extending my understanding beyond the concepts and definitions presented in Sections 1.1 and 2.2. As demonstrated in Table 22, the findings made visible what these concepts look like in practice, informing my recognition of the conditions necessary for the effective development of CT in early childhood settings for both educators and children. I now conceptualise computational thinking in early childhood is as a play-based, socially mediated approach to problem-solving, in which children plan, sequence, recognise patterns, break down and refine their ideas through exploration, persistence, and interaction, with their thinking supported and extended through educator dialogue, scaffolding, and engagement with meaningful tools. Collectively, the findings in Theme 1 establish a conceptual foundation for CT pedagogy and provided the basis for the development of knowing how, explored in the following section.

### *5.1.2 Knowing How: Collaborative Inquiry and the DISC Framework*

The findings from Theme 2 (Section 4.2, p. 155) respond to sub-question 2 and demonstrate that collaborative inquiry enabled the development of knowing how: pedagogical knowledge to design CT learning experiences. As mapped in Table 21, the educators' pedagogical development was shaped by how they experienced Complexity and Ease of Use with CT and PRK over time. Initially, designing CT learning experiences felt unfamiliar and challenging. However, the facilitating conditions embedded within the co-design process, access to PRK, scaffolded mentoring, peer dialogue, and time to reflect, reduced perceived

complexity and helped educators connect CT to familiar ECEC practice. Through iterative cycles of planning, play, and reflection, purposeful design began to feel achievable, marking a shift toward Effort Expectancy and growing confidence in applying CT ideas. The co-design intervention created a structured yet flexible space for translating CT conceptual understanding into pedagogical action through iterative design cycles (Figure 27) of planning, play, and debrief. These iterative structures, identified in Table 21 as facilitating conditions (time, mentoring, collaborative spaces), functioned as relational and experiential supports for building pedagogical competence and reducing perceived complexity. To explain this process more clearly, I developed the DISC Framework for Collaborative Inquiry in Designing Early Childhood Computational Thinking Learning Experiences (Figure 39) as an original conceptual model that captures how collaborative inquiry functioned in practice and enabled educators to translate emerging CT knowledge into intentional pedagogy

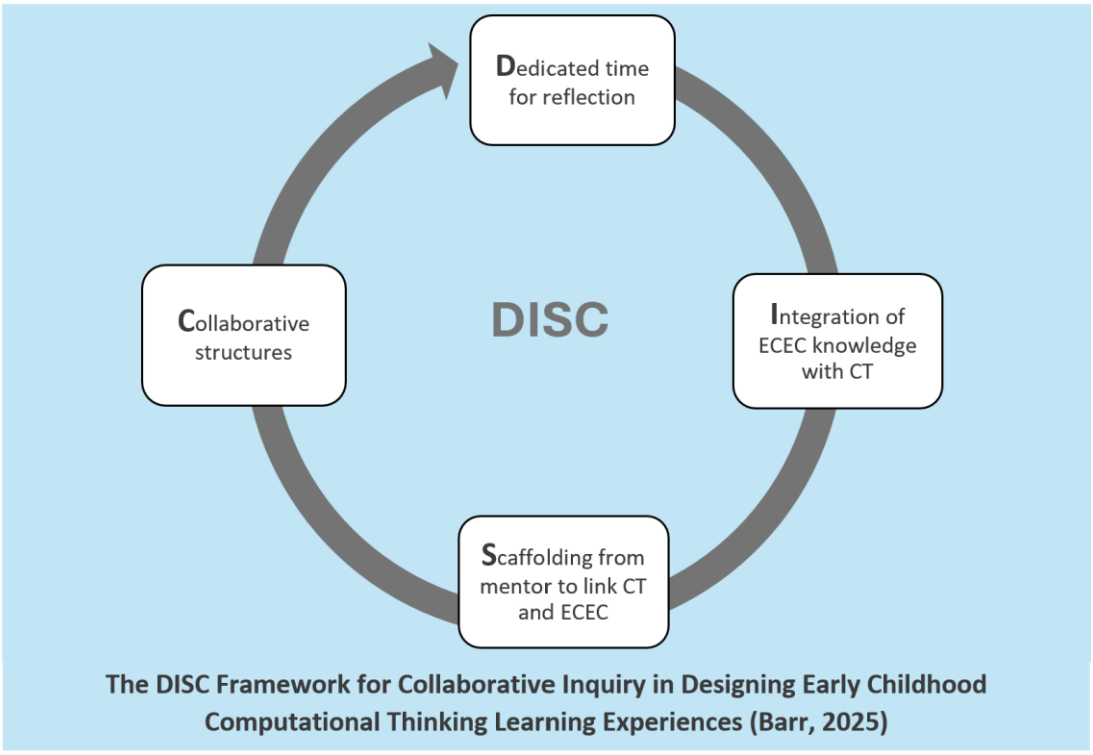



**Figure 40: The DISC Framework for Collaborative Inquiry (Barr, 2025)**

Four interrelated facilitating conditions supported this D.I.S.C process:

1. **Dedicated time** for reflection to think about potential successes, challenges and inform next steps (Papert, 1980).
2. **Integration** of existing ECEC knowledge with CT (Campbell-Barr, 2017; 2018; 2019)
3. **Scaffolding** from myself as researcher-mentor to link CT concepts to familiar ECEC curriculum goals (Rogoff, 1990; 2003)
4. **Collaborative structures** that created shared professional learning spaces (Rogoff, 1990, 2003; Barron et al., 2007; Van den Beemt and Diepstraten, 2016).

These conditions correspond to *Effort Expectancy* and *Subjective Norm* in UTAUT, demonstrating that pedagogical development was shaped by both structural supports and social influences. As the educators experienced successful outcomes (e.g., programming mTiny to draw geometric shapes), they built both confidence in ease of use and belief in positive outcomes, aligning with *Perceived Behavioural Control* and *Performance Expectancy* (Venkatesh et al., 2003). The *DISC Framework for Collaborative Inquiry*, Figure 37 developed through my analysis, captures this relational, iterative, and practice-based development. It illustrates how collaborative inquiry enabled purposeful pedagogical design, demonstrating that the educators did not simply acquire knowledge but constructed intentional CT pedagogy within their own contexts.

The DISC framework is underpinned by the Iterative Design Cycle (Figure 28), which enabled the educators to translate conceptual understanding into pedagogical action.

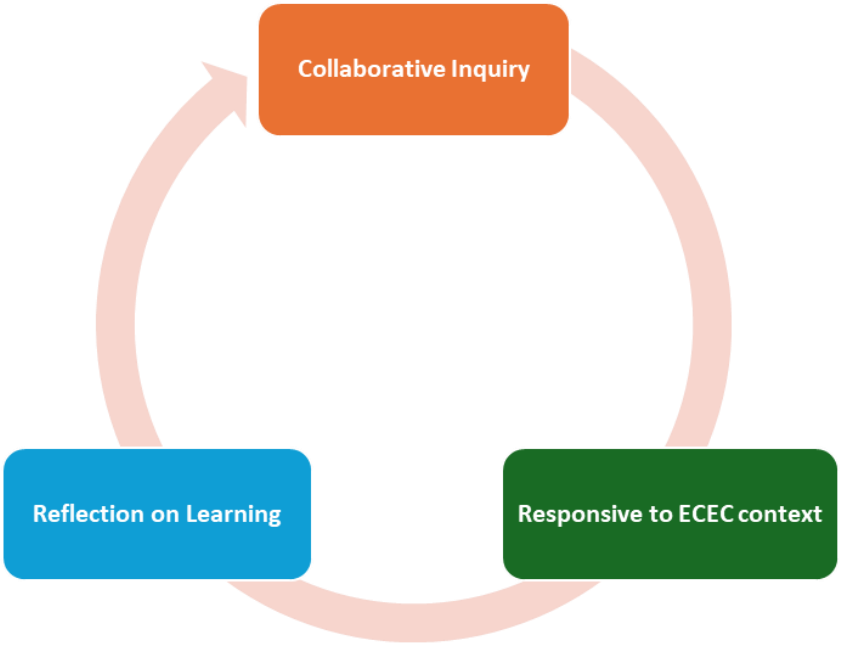



**Figure 28: Features of the Iterative Design Cycle**

As discussed, in Section 4.2.1, p. 157, collaborative cycles of planning, play, and debrief helped the educators integrate constructionist ideas with their existing ECEC knowledge, resulting in an emerging intentional pedagogy (Fleer, 2011; 2021) that embedded CT within purposeful play. This process drew on the combined theoretical perspectives, constructionism (Papert, 1980, 2000, 2005), sociocultural learning (Rogoff, 1990, 2003), and ECEC pedagogical knowledge (Campbell-Barr, 2017, 2018, 2019).

Situated in meaningful practice, the educators designed, enacted, and reflected on CT learning experiences through purposeful play with the PRK, mTiny. Collaborative inquiry, supported by my role as mentor, fostered confidence, encouraged reflective reasoning, and scaffolded the application of CT concepts and pedagogical strategies in practice (Appendix Y). As educators experienced successful outcomes, such as programming mTiny to draw geometric shapes, they developed both *Effort Expectancy* (confidence in ease of use) and *Performance Expectancy* (belief in positive outcomes), aligning with *Subjective Norm* and *Perceived Behavioural Control* in Table 21. Developed in response to the emerging findings,

the DISC Framework captures this relational, iterative, and practice-based development. It demonstrates how collaborative inquiry supported educators in designing meaningful CT learning experiences and facilitated a shift toward intentional CT pedagogy grounded in their own ECEC contexts.

### *5.1.3 Knowing Why: Beliefs, Values, and Understandings of Purposeful Play and Intentionality in CT Learning*

Theme 3 (Section 4.3, p.178) responds to sub-question 3 and represents the knowing why dimension of professional learning: developing the pedagogical reasoning, values, and understanding of why developing young children's computational thinking through purposeful play with programmable robotic kits is valuable learning. As illustrated in Table 21, this phase aligns with UTAUT's Performance Expectancy, where attitudinal supports, particularly reflective dialogue, mentor guidance, and experiential evidence, influenced educators' motivation to integrate CT into practice. From the outset, the educators valued play as a context for nurturing children's independence, problem-solving, perseverance, and collaboration (NCCA, 2024). Throughout the co-design process, they developed a more nuanced understanding of how purposeful play with PRK could strengthen these dispositions while also introducing CT concepts. Observing children's engagement served as powerful evidence that CT was compatible with their values and pedagogical aims, helping educators reconceptualise it as meaningful and worthwhile. Reflective dialogue and mentor scaffolding enabled the educators to examine how CT connected with their values, while practical evidence of children's perseverance and reasoning affirmed its relevance to early childhood pedagogy. These value-based supports reflect UTAUT's sub-constructs of compatibility, perceived usefulness, and job-fit, strengthening educators' motivation and professional identity in relation to CT. Drawing on constructionist principles (Papert, 1980; 2000) and Campbell-Barr's (2019) emphasis on relational professional knowledge, the educators reconceptualised CT as part of intentional, high-quality pedagogy Their emerging intentional

pedagogy (Fleer, 2011; 2021) reflected a developing pedagogical stance, as they learned to balance children's agency with purposeful learning goals. This was evident in the educators ability to step in or step back (Ackermann, 2003), responding to children's choices while introducing appropriate challenge; aligning with Aistear's (NCCA, 2024) reflective cycle of notice–nurture–respond–reflect.

Collectively these three dimensions, *knowing what*, *knowing how*, and *knowing why*, illustrate a gradual evolution through which educators progressed from building conceptual understanding, to applying CT knowledge in practice, to recognising the pedagogical value of CT within purposeful play. Each theme reflects a distinct aspect of professional learning, yet as presented in Table 21, they were not experienced in isolation. Their interdependence is illustrated in Figure 41, which synthesises how the three themes align with the theoretical perspectives and Department of Education's (2023) professional-learning dimensions.

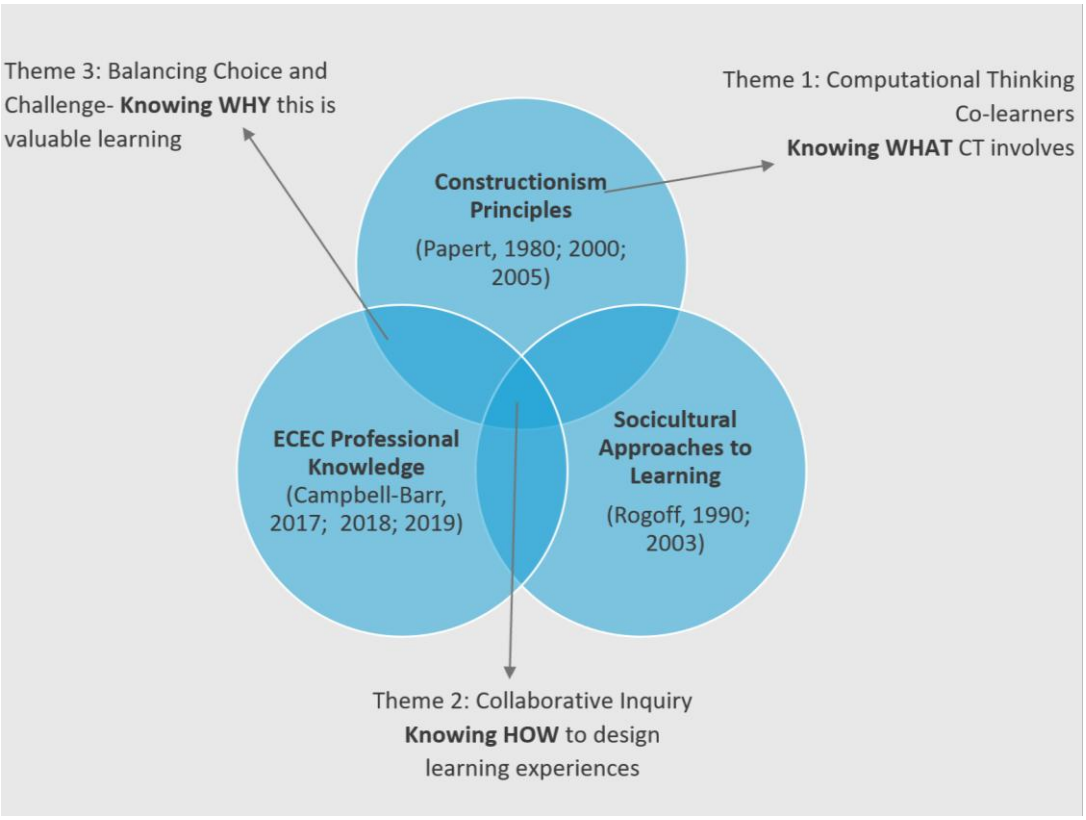



**Figure 41: Interconnection: Themes, Theoretical Perspectives and Professional Learning Dimensions**

This synthesis demonstrates how knowledge, practice, and beliefs operated as mutually reinforcing elements in shaping educators' engagement with CT. Section 5.2 builds on this synthesis by examining the conditions that enabled this professional-learning process. To conceptualise how these conditions functioned in combination, they were analytically clustered into three interrelated dimensions, structural, experiential, and attitudinal, forming the *SEA framework of Structural, Experiential, and Attitudinal Supports*.

## 5.2 From Themes to Learning Ecology: The SEA Framework of Structural, Experiential, and Attitudinal Supports

Building on the synthesis in Figure 41, this section examines the facilitating conditions that supported the educators' development of *knowing what*, *knowing how*, and *knowing why*. Through analysis of the patterns across the three themes, I constructed the *SEA Framework of Structural, Experiential, and Attitudinal Supports* as a conceptual model that captures how structural, experiential, and attitudinal supports shaped educators' professional learning within an ecology of practice.

### *5.2.1 Five Interrelated Facilitating Conditions*

Analysis of the three themes identified five interrelated facilitating conditions that, in combination, created the context in which educators' knowledge, skills, and values could evolve.

1. Time and space for iterative cycles of inquiry, enabling sustained engagement, reflection, and refinement of practice (Papert, 1980; Rogoff 1990).
2. Mentor support and peer collaboration, providing dialogic scaffolding and shared problem-solving (Rogoff, 1990, 2003).
3. Intentional choice of PRK (mTiny), whose design features supported both CT and holistic developmental goals (Papert,1990; Bers et al., 2022; Sullivan et al., 2017).

4. Situated learning within educators' own ECEC contexts, ensuring relevance and authentic application (Rogoff, 1990; Johnston et al., 2020; Stevenson et al., 2019).
5. Recognition of CT as valuable learning, aligning new practices with existing pedagogical values (Campbell-Barr, 2017a; 2019a).

**Time and space for iterative cycles of inquiry** enabled cycles of planning, play, and reflection, supporting educators to combine emerging CT knowledge with tacit pedagogical insights. This cumulative and iterative structure supported the educators to contextualise their evolving CT knowledge, combining 'explicit' CT concepts (algorithmic thinking, decomposition, debugging) with 'tacit' everyday ECEC pedagogical knowledge and insights.

**Mentor support and peer collaboration** offered scaffolding and dialogic spaces for co-construction of CT skills and strategies. Collaborative inquiry extended pedagogical strategies, built confidence, and supported the educators to design CT learning goals and purposeful play with PRK.

**The intentional choice of mTiny as the PRK** shaped both children's and the educators' learning as its design features aligned with developmental and pedagogical aims. Programming mTiny with a tap pen and direction coding cards separated planning from action, making algorithmic steps visible and supporting embodied CT learning. The emotions and feelings cards, together with the robot's interactive responses, created opportunities for socio-emotional learning and wellbeing. The open-ended map blocks also enabled imaginative storylines and designs, fostering creativity, exploration, and agency. In this way, mTiny's affordances supported both CT practices and the broader creative and socio-emotional dispositions valued in ECEC.

**Situated learning within the educators' own context** enabled meaningfully application and adaptation of CT learning experiences. Working directly with the children in their settings enabled the educators to draw on existing ECEC practice knowledge and make context-sensitive pedagogical decisions.

**The educators' recognition of CT as a form of valuable learning** in ECEC emerged as an essential condition. They came to view purposeful play with PRK as consistent with play-based, child-centred pedagogy that fostered valued dispositions such as perseverance, problem-solving, and independence (NCCA, 2024). This recognition contributed to their evolving beliefs, enabling them to embrace CT as part of intentional early learning and to expand their understanding of valuable learning.

Together, these structural (time, mentoring), experiential (hands-on inquiry), and attitudinal (value alignment) supports formed a cohesive ecology enabling educators to design CT learning experiences through purposeful play with PRK. From this synthesis, I developed the SEA Framework as a conceptual model that clusters these five facilitating conditions and conceptualises professional learning as an ecological process rather than a linear one (Table 23).

**Table 23: Mapping Facilitating Conditions with Structural, Experiential, Attitudinal Supports**

| Five Facilitating Conditions | Structural/ Experiential/ Attitudinal Supports |
|---|---|
| Time and space for inquiry | Structural |
| Mentor support and peer collaboration | |
| Choice and affordances of the PRK, mTiny | |
| Situated Learning | Experiential |
| Recognition of CT as valuable learning | Attitudinal |

### *5.2.2 The SEA Framework*

The SEA Framework captures the conditions that shaped educators' professional learning throughout the co-design intervention:

- **Structural supports** (e.g., time, mentoring) created the organisational space for iterative inquiry.
- **Experiential supports** (e.g., hands-on engagement, situated learning) enabled educators to develop CT knowledge and pedagogy through practice.
- **Attitudinal supports** (e.g., value alignment, belief transformation) nurtured motivation and shaped educators' willingness to adopt CT purposefully within play.

The terms Structural, Experiential, and Attitudinal were selected through a synthesis of the findings and the literature to capture three interrelated dimensions of educators' professional learning within a learning ecology. The structural dimension captures those organisational, material, and relational conditions that enabled the educators participation in the professional learning process. This aligns closely with the concept of facilitating conditions in technology adoption research, which includes the availability of time, situated practice and access to resources (Venkatesh et al., 2003). Across the findings, elements such as time, mentoring, collaboration, and access to PRK (mTiny) functioned as enabling infrastructures for engagement. These map directly onto learning ecology literature, where learning is understood as being distributed across material and social resources (Barron, 2006), and research on teacher professional development, which highlights the importance of resources, infrastructure, time and being within a culture that values technology as a pedagogical tool as prerequisites for meaningful professional learning (Stevenson et al., 2019).

The term experiential was selected to capture the practice-based and situated nature of the educators professional learning during the intervention. It reflects the constructionist and socio-cultural perspectives in which knowledge develops through participation, inquiry, and

hands-on engagement (Rogoff, 1990; Papert, 1980). Co-learning with the children formed an important component of the experiential support; educators were positioned as co-learners alongside children, fostering collaborative creation and shared understanding (Johnston, 2019). These experiences align with research demonstrating that practice-based, collaborative, and contextually situated professional learning is important for developing competence and confidence with digital technologies (Stevenson et al., 2019; Vidal-Hall et al., 2020). The attitudinal term was selected to reflect the importance of the educators' beliefs, values, and dispositions in shaping their engagement with CT, PRK and new purposeful play practices. This dimension emerged in the findings, particularly in educators' recognition of CT as valuable learning, and their evolving alignment between CT and play-based, child-centred pedagogy. Learning ecology research emphasises that along with access to structural resources, professional learning involves personal positioning factors, including beliefs, identities, and motivations, which evolve over time within specific contexts (Sangrà and Raffaghelli, 2019; Van den Beemt et al., 2016). Professional learning must therefore engage educators' values and motivations to result in meaningful change.

Together, these Structural, Experiential and Attitudinal (SEA) supports formed a learning ecology in which the educators' CT knowledge, pedagogical practice, and professional values evolved in mutually reinforcing ways (Barron, 2004, 2006; Sangrà and Raffaghelli, 2019; Stevenson et al., 2019).

As illustrated in Figure 42 The SEA Framework conceptualises professional learning as an interconnected radial structure, where no single support operates independently. Instead, the reciprocal influence of structural, experiential, and attitudinal supports (Barron, 2006; Sangrà, Raffaghelli, and Guitert-Catasús, 2019) enabled educators to develop conceptual, pedagogical, and value-based understandings of CT through purposeful play with PRK.

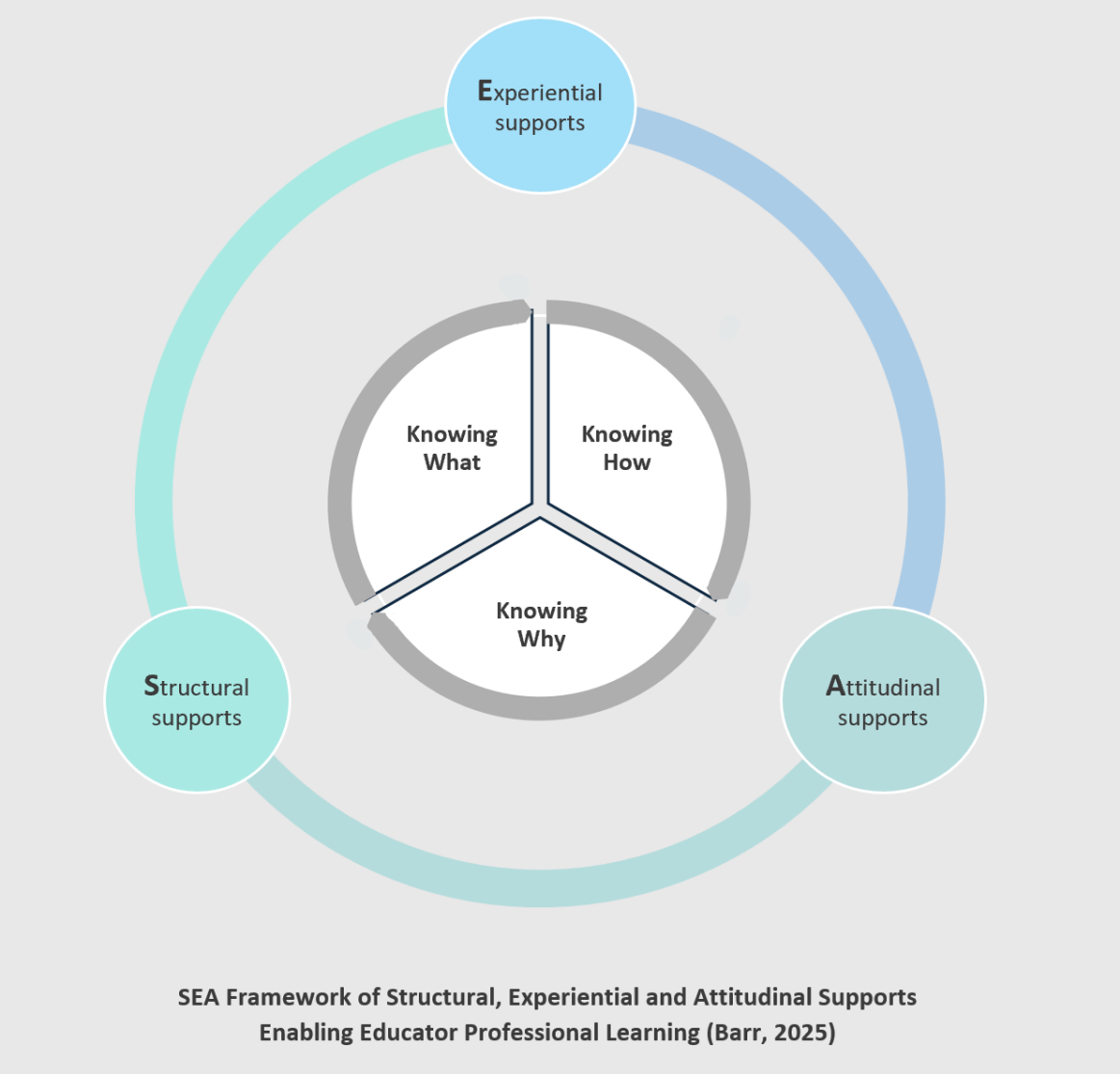



**Figure 42: SEA Framework of Structural, Experiential, and Attitudinal Supports (Barr, 2025)**

### *5.2.3 The Relationship Between SEA and DISC Frameworks*

While the SEA Framework conceptualises the conditions that supported the educators' learning, while the DISC Framework, introduced in Section 5.1.2, characterises the process through which collaborative inquiry occurred. In this sense, the DISC framework functioned within the wider SEA framework learning ecology, representing one mechanism through which learning was enacted. Figure 43 illustrates how the DISC framework sits within the broader SEA learning ecology.

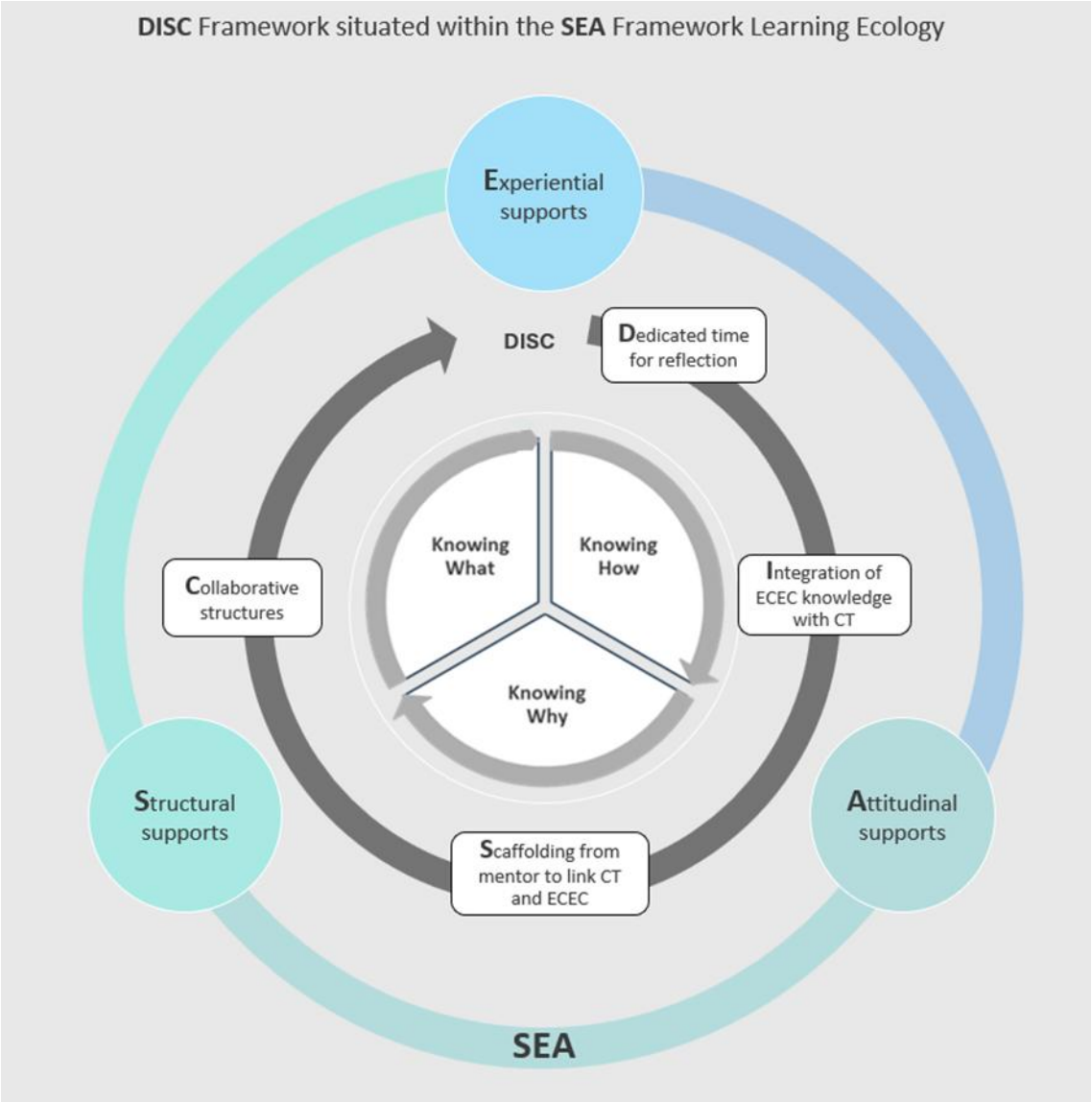



**Figure 43: Relationship of DISC Framework to the SEA Framework Learning Ecology**

DISC explains how educators engaged in collaborative inquiry to develop *knowing how*, whereas SEA captures the structural, experiential, and attitudinal supports that enabled this inquiry to take place. SEA provides the broader explanatory frame, identifying what conditions enabled learning, while DISC explains how these conditions were enacted to develop pedagogical competence.

By situating DISC within the SEA learning ecology, the study demonstrates that professional learning was both socially constructed and contextually supported, rather than occurring in isolation.

Together, these frameworks illustrate how the educators were able to:

- Build conceptual understanding (knowing what)
- Translate CT understanding into pedagogical practice (knowing how)
- Recognise CT as valuable and meaningful within play-based pedagogy (knowing why)

The SEA Framework therefore responds directly to the research question by identifying the facilitating conditions that supported educators to design CT learning experiences through purposeful play with PRK. This ecological account provides the foundation for the conceptual model, of professional learning for supporting children's computational thinking in early childhood, presented in Section 5.3.

## 5.3 A Model of Professional Learning

The synthesis of findings suggests that professional learning for supporting children's computational thinking in early childhood is best understood as an interconnected professional-learning ecology (Figure 44). This ecology comprises three interdependent dimensions of professional learning; knowing what, knowing how, and knowing why, that evolved through collaborative inquiry processes (captured in the DISC Framework) and were enabled by structural, experiential, and attitudinal supports (captured in the SEA Framework Section 5.2). Together, the DISC and SEA Frameworks, both developed through this study, form an integrated model of professional learning that explains how the educators' conceptual, pedagogical, and value-based understandings of CT developed throughout the intervention. This ecological model illustrates that learning did not occur linearly, but emerged through reciprocal relationships between knowledge, practice, context, and values.

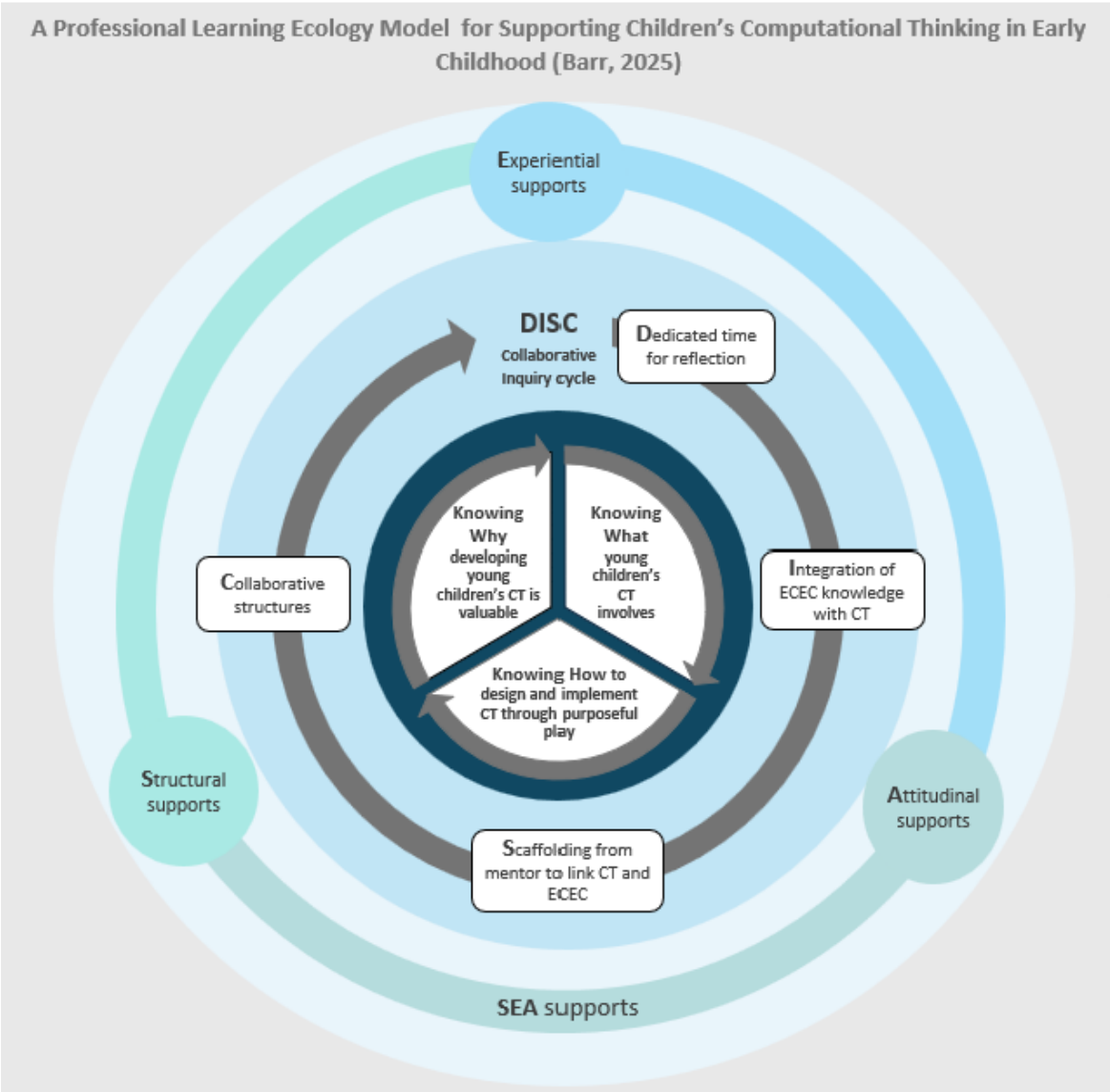



**Figure 44 A Professional Learning Ecology Model for Supporting Children's Computational Thinking in Early Childhood (Barr, 2025)**

### *5.3.1 The Model as a Learning Ecology*

The conceptualisation of professional learning as an ecology aligns with perspectives that emphasise the dynamic and reciprocal relationships between people, tools, contexts, and activity (Barron, 2004, 2006; Sangrà and Raffaghelli, 2019). In this study, educators' learning emerged through their interactions with children, colleagues, the PRK, and me as researcher-mentor, within the affordances and constraints of their everyday ECEC environments. In Bronfenbrenner's (1994) terms, learning was context-embedded; in Barron's (2006) terms, it reflected the "intertwining of person and context" (p. 196).

Consistent with these perspectives, the model developed in this study conceptualises professional learning not as a linear sequence but as a relational configuration in which knowledge, practice, and beliefs continuously interact. The three dimensions of knowing are mutually reinforcing:

- Knowing what (conceptual knowledge of CT) informs pedagogical decisions.
- Knowing how (pedagogical knowledge) deepens conceptual understanding.
- Knowing why (values and purposes) sustains motivation and shapes practice.

These recursive relationships reflect the feedback loops characteristic of learning ecologies (Barron, 2004; Sangrà et al., 2019), where insights reshape practice and practice generates new insights. In essence, learning and practice influence one another over time, creating a continuous cycle of improvement.

### *5.3.2 Integrating DISC and SEA within the Model*

Within this learning ecology, the DISC Framework represents the process mechanism through which educators primarily developed knowing how. while also deepening knowing what and knowing why. Through iterative cycles of designing, implementing, reflecting, and refining, educators collaboratively made sense of CT and its pedagogical application. These inquiry processes supported both experimentation and peer-supported reflection, leading to increasingly intentional CT practice.

The SEA Framework, in contrast, describes the *conditions* that made such learning possible. These comprised:

- **S**tructural supports (e.g., time, mentoring).
- **E**xperiential supports (e.g., hands-on engagement with PRK in situ).
- **A**ttitudinal supports (e.g., value alignment and belief transformation).

These conditions shaped educators' opportunities for inquiry, their ability to translate conceptual knowledge into practice, and their willingness to integrate CT within play-based learning. Viewed together, DISC operates within SEA. DISC explains *how* educators engaged in inquiry to make pedagogical decisions; SEA explains *what* supported that inquiry to occur. Their interaction reflects a learning ecology in which opportunities for action, reflection, and meaning making are distributed across people, resources, and activity settings (Barron, 2004, 2006). These reciprocal relationships reinforce that professional learning was not an individual cognitive process, but a situated, relational, and iterative endeavour shaped by structural affordances, shared inquiry, and evolving pedagogical beliefs.

### *5.3.3 ECEC Professional Learning*

This model (Figure 41) advances understandings of professional learning in ECEC in several ways. First, it illustrates that developing CT pedagogy is not simply a matter of acquiring conceptual knowledge, but of fostering a supportive ecology in which educators can explore, reflect, and recognise value in new practice. As educators engaged in constructionist play with the programmable robotic kit (PRK), they developed *knowing what*, a conceptual understanding of CT ideas such as algorithmic thinking, decomposition, and pattern recognition, and *knowing how*, the pedagogical knowledge needed to design and refine CT learning experiences. Alongside these developments, *knowing why* emerged, as educators recognised that purposeful play with PRK aligned with valued early-childhood dispositions, including collaboration, perseverance, and problem-solving. This value alignment strengthened their motivation to integrate CT intentionally into practice.

This model also contributes new knowledge on ECEC professional learning more generally by illustrating how conceptual, practical, and attitudinal learning are mutually reinforcing rather than sequential. Conceptual understanding informed pedagogical decisions; pedagogical experimentation deepened conceptual insight; and both were sustained by professional values. In this way, learning was dynamic, relational, and shaped by the educators' contexts, beliefs, and collaborative inquiry. Figure 45 generalises these insights as a more general version of the model by presenting a Professional Learning Ecology Model for Early Childhood Education and Care.

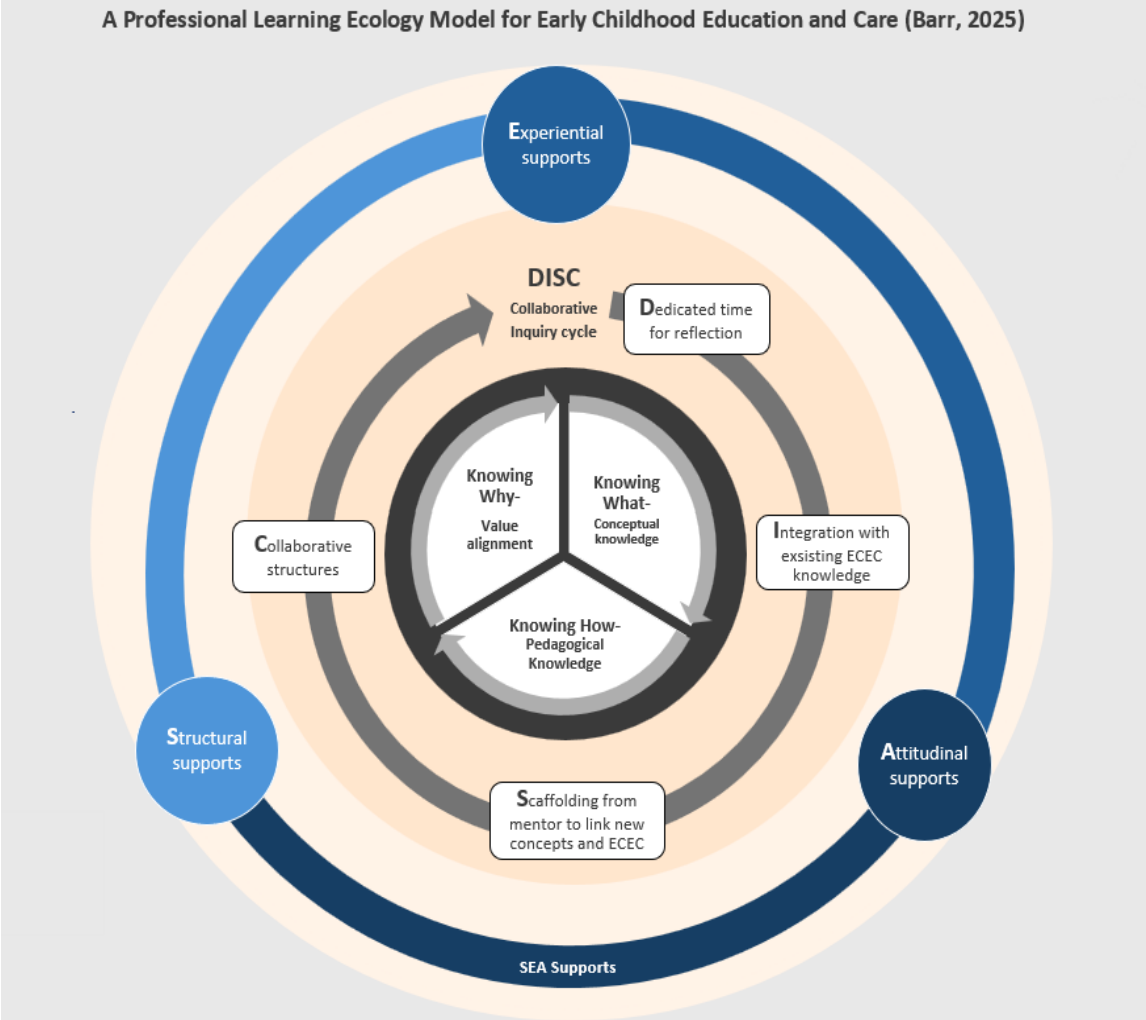



**Figure 45 A Professional Learning Ecology Model for Early Childhood Education and Care (Barr, 2025)**

Both versions on the model aligns with Campbell-Barr's (2019) framing of professional knowledge as relational and context-embedded. Educators' learning unfolded through

collaborative inquiry, reflective dialogue, and hands-on engagement with children and tools, consistent with ecological perspectives that emphasise reciprocal interactions among activity, people, and context. Taken together, the DISC and SEA frameworks developed in this study constitute a professional-learning ecology for early childhood education and care, in which educators' knowledge, practice, and beliefs evolve through iterative exchanges between collaborative inquiry and contextual supports. This ecological stance underscores the need for inquiry-rich environments that enable educators to develop relevant conceptual understanding and intentional pedagogy grounded in playful learning.

Table 24 outlines how the structural, experiential, and attitudinal supports identified in this study can be adapted beyond computational thinking to inform professional learning more broadly in ECEC.

**Table 24: Adapting Structural, Experiential, Attitudinal Supports for more General Professional Learning in ECEC**

| Five Facilitating Conditions for CT Professional Learning | Structural/ Experiential/ Attitudinal Supports | Five Facilitating Conditions for more General Professional Learning in ECEC |
|---|---|---|
| Time and space for inquiry | **Structural** | Time and space for inquiry |
| Mentor support and peer collaboration | | Mentor support and peer collaboration |
| Choice and affordances of **the PRK, mTiny** | | Choice and affordances of the **material resources** |
| Situated Learning | **Experiential** | Situated Learning |
| Recognition **of CT** as valuable learning | **Attitudinal** | Recognition of **new pedagogical focus** as valuable learning **for children** |

The DISC framework adaptations outlined in Table 25 illustrates how the collaborative inquiry conditions that supported educators' engagement with computational thinking can be translated to professional learning in a wider range of ECEC pedagogical areas.

**Table 25: Adapting DISC Framework facilitating conditions for more General Professional Learning in ECEC**

| The DISC Framework for Collaborative Inquiry in Designing Early Childhood Computational Thinking Learning Experiences | DISC Framework Facilitating Conditions | The DISC Framework for Collaborative Inquiry for more General Professional Learning in ECEC |
|---|---|---|
| Dedicated time for reflection to think about potential successes, challenges and inform next steps (Papert, 1980). | Dedicated Time for Reflection | Dedicated time for reflection to think about potential successes, challenges and inform next steps (Papert, 1980). |
| Integration of existing ECEC knowledge with **CT** (Campbell-Barr, 2017; 2018; 2019) | Integration of existing ECEC knowledge | Integration of existing ECEC knowledge with **new conceptual knowledge** (Campbell-Barr, 2017; 2018; 2019) |
| Scaffolding from myself as researcher-mentor to link **CT** concepts to familiar ECEC curriculum goals (Rogoff, 1990; 2003) | Scaffolding from Mentor | Scaffolding from myself as researcher-mentor to link **new** concepts to familiar ECEC curriculum goals (Rogoff, 1990; 2003) |
| Collaborative structures that created shared professional learning spaces (Rogoff, 1990, 2003; Barron et al., 2007; Van den Beemt and Diepstraten, 2016) | Collaborative Structures | Collaborative structures that created shared professional learning spaces (Rogoff, 1990, 2003; Barron et al., 2007; Van den Beemt and Diepstraten, 2016) |

Although developed through a focus on computational thinking, the model captures processes of learning that are transferable, highlighting how educators' knowledge, practice, and beliefs evolve through sustained, context-sensitive inquiry. Figure 42 builds on this insight, presenting a Professional Learning Ecology Model for Early Childhood Education and Care that synthesises these elements into a coherent and transferable framework.

## 5.4 Summary

The synthesis of findings illustrates that facilitating conditions in this study functioned as a professional-learning ecology, comprising structural, experiential, and attitudinal supports. Structural supports such as time, collaboration, and mentoring created the conditions for iterative inquiry. Experiential supports, including hands-on engagement with PRK and situated reflection within the educators' own practice, enabled the construction and application of CT-focused pedagogical knowledge. Attitudinal conditions such as value

alignment, reflective dialogue, and recognition of CT's importance, underpinned educators' motivation, and interest to integrate CT meaningfully into play-based practice. Together,

these interrelated supports enabled educators to progress from developing conceptual understanding of CT (knowing what), to applying CT pedagogically in purposeful play (knowing how), to recognising its alignment with valued early-childhood dispositions and practices (knowing why). Professional learning therefore unfolded as an iterative, relational process that intertwined knowledge, practice, and belief.

The co-design intervention provided an inquiry-rich, collaborative context that aligns with constructionist principles (Papert, 1980, 2000, 2005), sociocultural theories of learning (Rogoff, 1990, 2003), and relational approaches to professional knowledge (Campbell-Barr, 2017, 2018, 2019). The SEA and DISC frameworks together illustrate how collaborative inquiry processes (DISC) were sustained by structural, experiential, and attitudinal supports (SEA), creating a professional-learning ecology for CT pedagogy. This ecological perspective demonstrates how interrelated supports enabled educators to design and implement CT learning through purposeful play with PRK.

In summary, the study demonstrates that educators' capacity to support young children's development of CT emerged through the dynamic interplay of knowledge, pedagogical practice, and professional values, sustained within a supportive learning ecology. The integrated SEA and DISC frameworks conceptualise this as a professional-learning ecology in which collaborative inquiry processes are both enabled and sustained by contextual supports. The following chapter presents the conclusions, implications, and recommendations arising from these findings and the development of the professional-learning ecology model, including its extension as a broader framework for professional learning in early childhood education and care, highlighting its significance for policy, practice, and future research.

# Chapter 6 Conclusion

This chapter synthesises the findings, building on the professional learning ecology model presented in Figure 41 to demonstrate the study's contributions to the emerging field of computational thinking (CT) in early childhood education and care (ECEC). It begins with an overview of the study and a summary of the key findings in relation to the overarching research question. The chapter then outlines the study's contributions to research, practice, and policy, followed by an acknowledgement of the methodological and contextual limitations. Finally, it concludes with a reflective account of how my professional and personal learning shaped both the study and my identity as a researcher-mentor, acknowledging the role of positionality in guiding interpretation, methodology, and meaning-making.

## 6.1 Overview of the study

This study addressed a gap in in the Irish ECEC context: how to integrate computational thinking (CT) in ways that are developmentally appropriate, playful, and responsive to children's agency and needs. Although national and international policy (DE, 2017, 2022; NCCA, 2024; OECD, 2023; GoI, 2024) increasingly emphasises digital literacy and CT as essential early learning skills, educators in Ireland continue to face barriers, including limited guidance, resources, and professional learning opportunities (DE, 2020; GoI, 2023a). These challenges are compounded by limited pedagogical and technical knowledge for embedding digital tools into purposeful play, as well as uncertainty about the educational value of young children's digital engagement (DE, 2020, 2023; GoI, 2023). To address these challenges, this study explored the facilitating conditions that enable early childhood educators to design purposeful play experiences that foster CT using programmable robotic kits (PRK).

The research aimed to support educators in an Irish early childhood setting to co-design and

implement purposeful play experiences for children aged 3–5 years. Although situated in a single setting, the study offers insights relevant to wider ECEC contexts where educators are seeking to integrate digital tools within play-based, child-centred pedagogy. The PRK (mTiny) was selected as a tangible digital tool aligned with constructionist learning and ECEC's playful, child-led principles, offering opportunities for children to explore algorithmic thinking, debugging, and pattern recognition in meaningful contexts.

Adopting a design-based research (DBR) approach, the study engaged two educators, Leah and Elaine and eleven children in a six-week iterative intervention involving collaborative planning, purposeful play with programmable robotic kits (PRK), and reflective debriefing The intervention was guided by an integrated theoretical framework combining constructionism (Papert, 1980, 2000, 2005), sociocultural theory (Rogoff, 1990, 2003), and the ECEC professional knowledge perspective (Campbell-Barr, 2017, 2018, 2019). Together, these perspectives align with Aistear (NCCA, 2024) framing children as active constructors of knowledge, educators as co-learners and guides, and pedagogy as intentional, responsive, and grounded in values of play, agency, and wellbeing.

The findings analysed in Chapter 4 and synthesised in Chapter 5 demonstrated that the intervention created conditions for the educators to build CT knowledge, explore pedagogical strategies, and refine their role in supporting purposeful play and computational thinking. Using a design-based research (DBR) approach, I worked as a researcher-mentor with the educators to facilitate this ongoing professional learning, supporting them in extending their knowledge, skills, beliefs, and pedagogical strategies for integrating CT within their curriculum.

Through this collaborative and iterative process, I generated new insights that informed my development of two interrelated frameworks. The DISC Framework for Collaborative Inquiry in Designing Early Childhood Computational Thinking Learning Experiences

(Figure 37), which captures the processes through which educators developed CT pedagogy, namely Dedicated time for reflection, Integration of existing ECEC knowledge, Scaffolding from myself as researcher-mentor and Collaborative structures creating shared professional learning spaces. The SEA Framework of Structural, Experiential, and Attitudinal Supports (Figure 39), which conceptualises the supports that enabled this learning. Together, these frameworks informed my development of a professional-learning ecology model (Figure 41), which conceptualises educators' learning as a dynamic interplay of knowledge, practice, and professional values shaped by contextual supports. Through the DBR process and my positionality as a researcher-mentor, new insights emerged that can guide the design of professional learning opportunities to foster educators' digital literacy and support the meaningful integration of CT within play-based curricula. Informed by the professional-learning ecology model I developed through this study; the following section summarises the key findings that informed this model and addresses the overarching research question.

## 6.2 Summary of Key Findings

The study explored the overarching research question:

*What are the facilitating conditions that support early childhood educators to design learning experiences that develop young children's computational thinking through purposeful play with programmable robotics kits in an Irish ECEC context?*

As presented in Chapters 4 and 5, the findings demonstrate that professional learning played a central role in enabling educators to design meaningful, play-based learning experiences that supported children's emerging computational thinking (CT). The educators engaged with CT as part of a relational, reflective, and practice-embedded process, shaped by their ongoing interactions with children, the programmable robotic kits (PRK), me as research-mentor and each other. Their professional learning unfolded across interconnected dimensions of knowing what CT looks like in early childhood, knowing how to design for CT through purposeful play, and knowing why it aligns with their existing pedagogical

values. These dimensions evolved in relation to one another, illustrating that conceptual understanding, pedagogical experimentation, and value-based reflection were mutually reinforcing rather than sequential. My synthesis of the findings from themes 1-3 in relation to these dimensions led to the emergence of two interrelated frameworks (DISC + SEA), presented in Chapter 5. Together, these frameworks informed my creation of a professional-learning ecology model that situates educator learning within an ecology of reflective, collaborative, and practice-based inquiry.

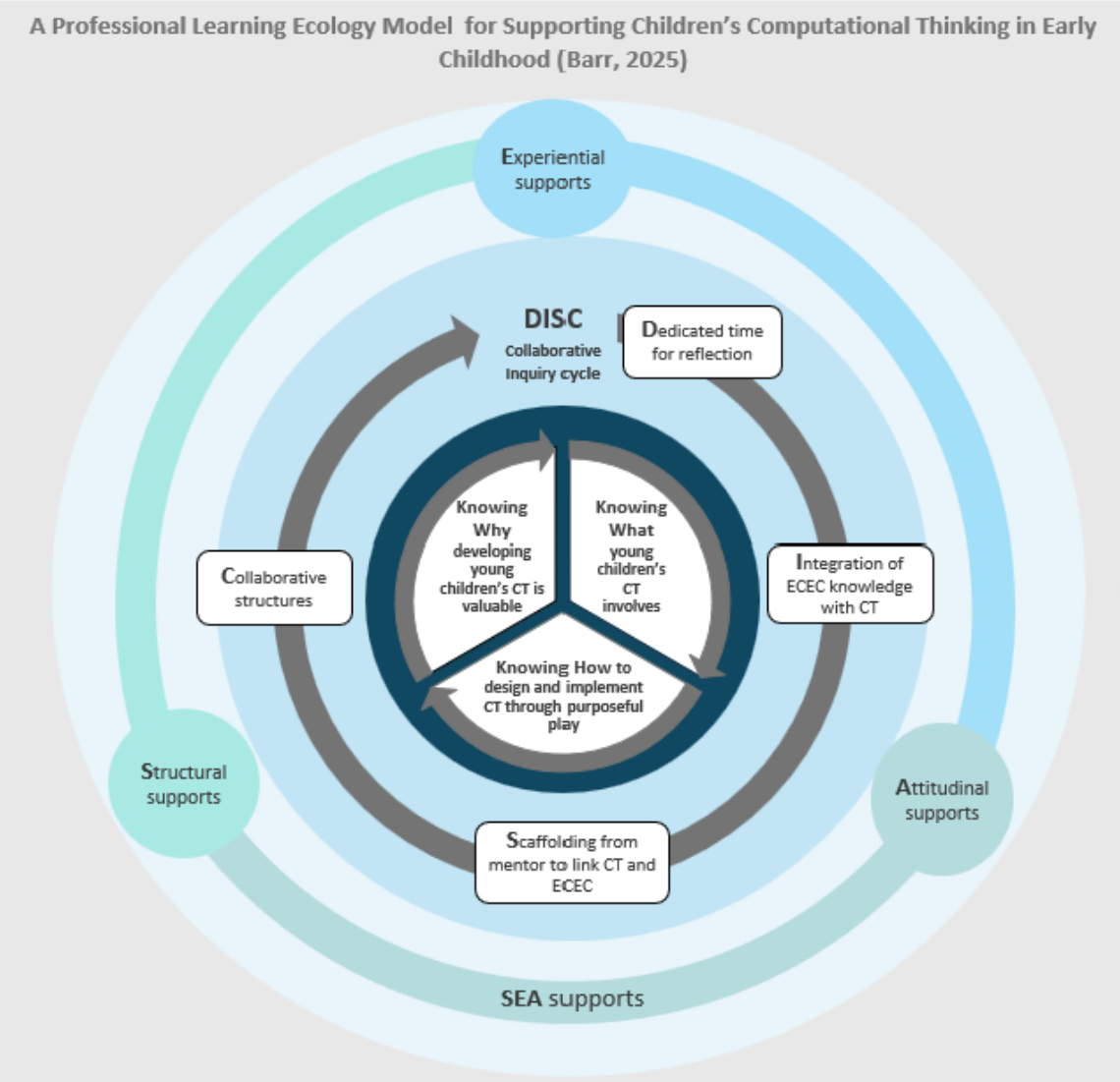



**Figure 44: A Professional Learning Ecology Model for Supporting Children's Computational Thinking in Early Childhood (Barr, 2025)**

In this way, the study responds directly to the research question by illustrating that knowing how (Pedagogy) required collaborative inquiry: the educators' ability to design purposeful

play was constructed through the iterative cycles captured in the DISC Framework. This inquiry depended on specific structural, experiential, and attitudinal (SEA) supports. Knowing what was fostered through constructionist hands-on co-design with the children and PRK, supporting a clearer understanding of CT and how it is visible in children's play. Knowing why (values) drove practice; recognising the alignment between CT and ECEC values, was a catalyst that led to the educators active engagement with the intentional design of learning experiences. Section 6.3 builds on these findings by outlining the study's significant contributions to research, practice, and policy, demonstrating how the professional-learning ecology model advances current understandings of CT pedagogy in early childhood.

## 6.3 Contributions of the Study

This section outlines how the study significantly contributes new knowledge to research, practice, and policy.

### *6.3.1 Contribution to Research*

From a research perspective, this study advances the emerging field of computational thinking (CT) in early childhood by addressing a key gap in existing literature. While many studies have focused on children's learning outcomes (OECD, 2023), this study foregrounds educator learning and the conditions that support their development of CT knowledge and pedagogy in their own early childhood setting. Methodologically, the study extends the use of design-based research (DBR) in ECEC by illustrating how iterative cycles of planning, play, and reflection can serve simultaneously as research processes and professional learning opportunities. This demonstrates how collaborative, practice-embedded inquiry can generate both theoretical insights and pedagogical enhancements providing a replicable model for future CT and digital pedagogy research. Theoretically, the study contributes a novel synthesis of constructionism, sociocultural learning theory, and ECEC professional knowledge. In line with constructionist principles (Papert, 1980, 2000, 2005), the educators

learning was shaped through hands-on co-learning with the children as well as their observation of the children's engagement with the PRK, which became an 'object to think with' through which powerful ideas of CT could be explored, tested, and reflected upon (Figure 19). A sociocultural lens further highlighted the relational and collaborative nature of learning for both educators and children. (Rogoff, 1990, 2003) (Papert's (1980) constructionism complements this perspective by positioning children as active constructors of knowledge who learn best through hands-on, meaningful projects. His emphasis on 'learning by doing' is particularly relevant in the context of PRK, where children create stories and then design the programme to enable mTiny enact the story. Constructionist learning is most effective when children are personally invested in what they create, whether that's programming mTiny to collect their favourite foods or design a city map for mTiny to explore. By integrating these perspectives with the professional knowledge base of ECEC (Campbell-Barr, 2017, 2018, 2019) the study conceptualises CT not only as a set of child learning outcomes but also as a process of co-learning between educators and children. This combined perspective recognises educators' tacit, practice-based knowledge as central to CT integration and demonstrates how professional beliefs and pedagogical strategies evolve alongside children's exploration of CT concepts.

Building on this the study proposes a model of professional learning that was informed by the DISC and SEA frameworks presented in Chapter 5. Together, these frameworks illustrate how the educators engaged in collaborative inquiry through iterative cycles of planning, play, and reflection with Dedicated time for reflection, Integration of existing ECEC knowledge, Scaffolding from myself as researcher-mentor and Collaborative structures creating shared professional learning spaces (DISC). This learning was further enabled by a set of Structural, Experiential, and Attitudinal (SEA) supports. At the centre the model (Figure 40) situates three interconnected dimensions of knowledge, knowing what, knowing

how, and knowing why, which are supported by facilitating conditions within the DISC and SEA frameworks.

While Venkatesh et al.'s (2003) construct of 'facilitating conditions' was not originally developed for early childhood education and care, I applied and adapted it through the research design and analysis to account for the relational and pedagogical nature of ECEC practice. Through my development of the SEA framework, the facilitating conditions construct has been extended to incorporate experiential and attitudinal dimensions, emphasising the role of educators' professional values, beliefs, and reflective inquiry in shaping the integration of digital technologies. In doing so, my development of a model of professional learning advances theoretical understanding of how educators interpret, adopt, and enact CT within play-based, relational pedagogies characteristic of ECEC. Although the model is grounded in CT, its structure and underlying principles extend beyond this domain. As presented in Chapter 5 (Figure 44), the professional learning ecology can be conceptualised more broadly as a model for ECEC professional learning, capturing how educators' knowledge, practice, and values evolve through relational, context-embedded, and inquiry-driven processes. This adapted version represents a key contribution of the study, positioning the model as both domain-specific and transferable across areas of early childhood pedagogy.

Finally, the study contributes new insights into the interplay between educators' beliefs and pedagogical practice in the context of CT integration. It highlights that professional identity, and values are not fixed but can evolve through structured opportunities for co-learning and collaborative inquiry. This nuanced understanding positions educator practice changes as a socially mediated and value-driven process of professional learning.

### *6.3.2 Contribution to Practice*

This study contributes to practice by offering a conceptualisation of computational thinking (CT) in early childhood as a play-based, socially mediated approach to problem-solving, in which children plan, sequence, recognise patterns, and break down and refine their ideas through active exploration, persistence, and interaction, with their thinking supported and extended through educator dialogue, scaffolding, and engagement with meaningful tools. This conceptualisation supports professional learning providers by offering a clear, practice-oriented way of developing CT with educators and their understanding of how young children's development of CT can be supported within ECEC playful learning contexts.

The findings of this study demonstrate that computational thinking (CT) can be meaningfully integrated into early childhood education and care (ECEC) through pedagogical approaches that align with play-based and child-centred principles. This aligns with Aistear (NCCA, 2024), which places renewed emphasis on playful STEM engagement, agency in learning, and inquiry-led exploration as foundations for early learning and development. A key implication for practice is that educators do not need to possess technical or knowledge expertise before engaging with CT and programmable robotic kits. Instead, professional learning should foreground educators as co-learners, both with children and with expert mentors, drawing on their professional knowledge of play, being child-led, and scaffolding. This reflects Aistear's (NCCA, 2024) positioning of educators as agentic and active co-learners who scaffold meaning-making and extend children's ideas through responsive and intentional interactions. This reframing of the educator's pedagogical positioning, from observer to intentional facilitator, emerges as a key insight for practice and positions CT as a natural extension of everyday ECEC practice rather than a specialised or separate domain. This positioning of CT aligns with Aistear's (NCCA, 2024) view of play as a meaningful context for enquiry, problem-solving and cognitive development.

The study also highlights the importance of iterative, practice-embedded professional learning as a facilitating condition for developing CT pedagogy. Educators' professional growth occurred through cycles of planning, play, and reflection, in which conceptual knowledge (knowing what), pedagogical skill (knowing how), and values alignment: (knowing why CT and purposeful play complement existing play-based and child-centred principles), evolved together. This implies that effective professional learning for CT should mirror these iterative processes, providing time and space for sustained inquiry, collaborative reflection, and experimentation within authentic contexts. Such experiential learning environments enable educators to translate theoretical understanding into practice and to build confidence in designing purposeful play that supports both CT and holistic child learning and development.

A further implication for practice lies in advancing understandings of intentional pedagogy and purposeful play within ECEC. These approaches are not yet fully established in early childhood practice in the Irish context (French and McKenna, 2022) but are increasingly recognised as necessary for fostering STEM thinking and conceptual understanding (Fleer, 2011). The study illustrates how intentionality does not diminish children's inquiry-led play but enriches it: educators can design scenarios that balance children's choice, interests and previous experiences with structured challenges that promote perseverance, problem-solving, and CT development. This contribution aligns with the vision of the agentic educator (NCCA, 2024), who actively shapes and extends learning opportunities while respecting the centrality of play.

Therefore, ECEC practice should be guided by an understanding of CT as relational and co-constructed, where digital tools such as programmable robotic kits (PRK) mediate both child and educator learning. Embedded within collaborative, reflective, and play-based practice, CT becomes a shared process of inquiry and creativity, rather than a technical activity.

### *6.3.3 Contribution to Policy*

At the policy level, this study provides timely evidence to support the integration of digital literacy and computational thinking (CT) within early childhood education and care (ECEC) in ways that are developmentally appropriate and pedagogically coherent. Current national and international policy documents (e.g., OECD, 2023; NCCA, 2024; Government of Ireland, 2024) advocate strengthening digital literacy from the early years, yet there remains limited empirical research on how this can be enacted in practice. This study addresses that gap by illustrating how CT can be embedded through purposeful play and collaborative professional learning, offering a model that aligns policy intent with pedagogical reality.

The findings also contribute to ongoing debates on digital literacy in ECEC, an area that remains underdeveloped in Ireland's *Literacy, Numeracy and Digital Literacy Strategy* (GoI, 2024). By presenting a conceptualisation of CT in early childhood (Section 6.3.2) and demonstrating how CT can be integrated through purposeful play with programmable robotic kits, the study provides evidence of how digital literacy can be enacted in curriculum and pedagogy in ECEC.

This also responds directly to gaps identified in policy and addresses concerns raised in the *Oireachtas Joint Committee on Education Report* (2023), which emphasised the importance of including STEM (of which CT and PRK are included) in the ECCE Programme as a means of strengthening continuity of learning between the home and primary school. In alignment with the *Primary Curriculum Framework*'s emphasis on Being a Digital Learner (NCCA, 2023), this study demonstrates how playful, hands-on approaches to CT can provide a developmentally appropriate starting point for early digital literacy, supporting children's continuity of learning as they transition into primary education. Similarly, it aligns with the *STEM Education Policy Statement (2017–2026)* and with the Government of Ireland's (2023) commitment to developing a Digital Learning Strategy for ECEC, offering a concrete model of how policy aspirations can be realised in everyday practice. By offering a concrete

model of how CT can be meaningfully supported through play-based pedagogy and professional learning, this study demonstrates how policy aspirations can be translated into everyday practice and contributes to bridging the gap between policy vision and pedagogical implementation.

A further policy contribution lies in the area of professional learning. The findings of the study indicate that policies focused on workforce development should prioritise practice-embedded, collaborative professional learning as a key enabling condition for CT integration. The evidence demonstrates that educators' engagement with digital tools depends not only on access or skill development but also on opportunities for reflective inquiry, peer dialogue, and iterative experimentation within their own contexts. Therefore, an implication for professional learning policies in ECEC, is that they should move beyond one-off workshops toward co-design and inquiry-based models that support sustained professional growth. This aligns with OECD (2023) recommendations for collaborative and contextually relevant professional learning and with the *STEM Education Policy Statement (2017–2026)*, which calls for developing educators at all levels, including ECEC, to support children's STEM learning (of which CT and PRK are included).

Finally, the study demonstrates that digital learning and STEM policies should explicitly acknowledge play-based and relational pedagogies as valid pathways to developing CT and digital literacy. By evidencing how CT and ECEC pedagogies are compatible and mutually reinforcing, the findings contribute to policy debates about how digital learning can be incorporated meaningfully in early childhood settings. Incorporating these insights into national frameworks, such as Ireland's *Literacy, Numeracy and Digital Literacy Strategy* (GoI, 2024) and the promised Digital Learning Strategy for ECEC (GoI, 2023b), would ensure that CT is embedded as part of a holistic vision of early learning that values creativity, collaboration, and inquiry.

## 6.4 Limitations of the study

While this study generated valuable insights into supporting educators to foster computational thinking (CT) through purposeful play with programmable robotic kits (PRK), several limitations must be acknowledged. Firstly, the study was conducted on a small scale, involving two educators and 11 children in a single early childhood setting. Although this provided rich, in-depth data, the small scale and specific context limit the generalisability of findings. However, while context-specific, its findings have wider relevance for national and international ECEC contexts. By demonstrating how programmable robotic kits can be used within constructionist and sociocultural framings of learning, this research offers indicative insights for other early childhood contexts where similar inquiries about digital innovation and play-based practice are to be explored. Secondly, the six-week intervention restricted opportunities to observe longer-term changes in educators' practice or children's progression over time. However, within this timeframe, the study incorporated twelve PRK-based play-sessions, along with six planning meetings and twelve debriefs, providing a sustained and intensive cycle of practice and reflection. Research on early childhood interventions in computational thinking with PRK indicates that sustained programmes of four to twelve weeks are developmentally appropriate and often more effective for maintaining young children's engagement than longer, less intensive initiatives (Hall and McCormick, 2022; Gerosa et al., 2022). This design therefore balanced feasibility with depth, while recognising the absence of longer-term follow-up. Thirdly, my multi-role as researcher, participant observer and mentor can influence the educators' perspectives and practice (Cohen et al., 2018). This may have constrained objectivity; however, it also strengthened the study by enabling reflexive practices and triangulation of data sources (Lincoln and Guba, 1985). Despite these limitations, the study offers important insights into the conditions that can support educators' professional learning in this area and provides a strong foundation for further research and practice. The insights gained highlight

the need for further studies across diverse ECEC contexts, over extended timeframes. These implications are explored in the following section, which outlines recommendations for research, practice, and policy.

## 6.5 Recommendations

Building on the findings, implications, and limitations of the study, the following recommendations are proposed for future research, practice, and policy. These recommendations are directly informed by the professional learning ecology model developed in this study, including its broader application as a general framework for ECEC professional learning, which conceptualises educator learning through three interconnected dimensions of professional learning (knowing what, knowing how, and knowing why). These dimensions are supported by two complementary frameworks: the DISC framework, which captures the collaborative inquiry processes, and the SEA framework, which outlines the structural, experiential, and attitudinal supports that enable them. Together, they provide an evidence-based foundation for supporting educator professional learning in CT within ECEC.

### *6.5.1 Research Recommendations*

Future research should build directly on the professional learning ecology model developed in this study. Specifically, research should investigate how the model functions as a scalable professional learning framework for supporting CT pedagogy in diverse ECEC contexts. This could involve:

1. **Applying the Professional Learning Ecology Model Across Diverse ECEC Contexts**

   Research should trial the model using iterative cycles of design-based research (DBR) across settings with different educator experience and qualifications, digital familiarity, and pedagogical approaches. This would allow examination of how the three dimensions

of professional learning, and the DISC and SEA frameworks are enacted in practice and adapted to different contexts.

**2. Investigating Long-Term Impact**

Longitudinal research should examine how sustained engagement with the model influences educators' conceptual understanding of CT, intentional pedagogical decision-making, and children's CT development over time. This would provide evidence of how the model supports pedagogical change and professional identity development.

**3. Exploring Children's Perspectives and Experiences**

Complementing the educator-focused findings, further research should investigate how children interpret, engage with, and express CT ideas, particularly through purposeful play with PRK. Understanding children's voices and funds of knowledge would deepen the experiential insights underpinning the SEA framework's experiential dimension.

**4. Bridging CT with Early Mathematics and Digital Literacy**

Future studies should examine the intersections between early childhood CT, mathematical thinking, and digital literacy as part of a continuum of digital learning from ECEC to primary education (Walsh et al., 2024; O'Kane, 2016). This may inform the development of cohesive curriculum pathways aligned with Ireland's *Primary Curriculum Framework* (NCCA, 2023) and promised Digital Learning Strategy (GoI, 2023b).

Collectively, these research directions would validate and refine the model developed in this study, positioning it as a research-informed professional learning framework for supporting CT in early childhood education and care.

### *6.5.2 Practice Recommendations*

The findings highlight that professional learning for CT must move beyond one-off workshops. Instead, professional learning should mirror the iterative, collaborative, inquiry-

based structures of the DISC framework, enabling educators to build CT knowledge through practice.

1. **Adopt Iterative, Practice-Embedded Professional Learning Models**

   Professional learning should incorporate cycles of planning, play, reflection, and redesign, enabling educators to apply and refine CT pedagogy through authentic practice, consistent with the DISC framework and SEA's structural and experiential supports.

2. **Position Educators as Co-Learners**

   Professional learning should explicitly promote a co-learning stance, enabling educators to explore CT concepts alongside children. Facilitators should emphasise reflection, experimentation, and collaborative problem-solving over technical proficiency.

3. **Develop Practice Guides and Toolkits**

   Collaborate with sectoral organisations (e.g. Pobal, BetterStart) and curriculum support agencies such as the NCCA to create accessible practice guides and digital toolkits demonstrating how CT can be fostered through purposeful play with PRK. These resources should align with *Aistear (NCCA, 2024)* and be available through the *Aistear Siolta Practice Guide* and the *Nurturing Skills Learning Hub* (DCDE, 2025).

4. **Integrate Intentional Pedagogy and Purposeful Play in Practice**

   Educators should design play experiences that balance children's agency with intentional scaffolding and challenge. Incorporating CT concepts such as sequencing, debugging, and pattern recognition into familiar play contexts can deepen learning while maintaining the open-ended nature of play.

### *6.5.3 Policy Recommendations*

Policy must recognise that CT integration depends not only on access to technology, but on context-sensitive professional learning and the creation of enabling conditions, as captured within the SEA framework.

1. **Develop National Guidance on CT in ECEC**

   National guidance should articulate how CT can be meaningfully integrated within play-based pedagogy. This guidance should align with Aistear (NCCA, 2024) and the Primary Curriculum Framework (NCCA, 2023) to support continuity of learning between ECEC and primary education.

2. **Embed CT within Digital Literacy and STEM Strategies**

   The promised Digital Learning Policy Statement for ECEC (GoI, 2023b*)*, the future updates of the *Literacy, Numeracy and Digital Literacy Strategy* (GoI, 2024) and implementation plan should explicitly include CT as an integral component of early digital literacy (OECD, 2023). Similarly, the next iteration of the *STEM Education Policy Statement 2017–2026* (DE, 2017) and implementation plan updates should reflect the evidence from this study that CT can be enacted through purposeful play and highlight CT as foundational to STEM learning for early childhood.

3. **Embed Professional Learning Ecology Model in National Strategies**

   Policy should prioritise funding for practice-embedded, collaborative professional learning that supports educators to engage in co-design and inquiry cycles within their own settings, based on the professional learning ecology developed in this study. This aligns with OECD (2023) recommendations for contextually grounded professional learning and should move beyond one-off workshops toward sustained, reflective engagement.

4. **Ensure Equitable Access to Age-Appropriate Digital Tools**

   Investment is needed to ensure all early childhood settings have access to age-appropriate programmable robotic kits and related technologies and resources. Policy should address the digital divide between settings to support equitable CT learning opportunities for all children (OECD, 2023). Without equitable access, the enabling conditions of CT pedagogy, as identified in the SEA framework, cannot be created.

These recommendations translate the professional learning ecology model into policy terms, offering a pathway to align national aspirations for digital learning with pedagogical realities in ECEC settings.

## 6.6 Significance of the Study

This study makes a significant contribution to advancing understanding of how computational thinking (CT) can be meaningfully integrated within early childhood education and care (ECEC). Empirically, it identifies the facilitating conditions that enable educators to design CT learning experiences through purposeful play, offering rich qualitative evidence from the underexplored Irish ECEC context. Theoretically, it develops an original professional learning ecology model that conceptualises educator learning through the interrelated dimensions of knowing what, knowing how, and knowing why, grounded in constructionist, sociocultural, and professional knowledge perspectives. These dimensions are expressed through two complementary frameworks: the DISC framework, which captures the iterative and collaborative processes underpinning educator learning; and the SEA framework, which extends Venkatesh et al.'s (2003) model of facilitating conditions by identifying the structural, experiential, and attitudinal supports required to enact CT in practice. Together, these frameworks deepen theoretical understanding of how educator learning, professional identity, and technology adoption interact in early childhood contexts. Methodologically, the study demonstrates how design-based research (DBR) can function as both a research approach and a professional learning process, generating reciprocal benefits for theory and practice. Through iterative cycles of co-design, reflection, and refinement, DBR positioned educators not as recipients of innovation but as active co-constructors of knowledge. This approach generated reciprocal benefits for theory and practice, highlighting DBR as a viable methodology for ECEC professional learning research more broadly. The study holds practical and policy significance, it evidences that CT and play-based pedagogy are not only compatible but mutually reinforcing, positioning

educators as co-learners who integrate digital technologies in ways consistent with ECEC values. These insights inform professional learning design by emphasising collaborative, practice-embedded inquiry as a foundation for pedagogical change. These insights provide a foundation for designing professional learning that is embedded in practice, honours educator agency, and aligns with the existing values of ECEC. At a policy level, the study contributes timely evidence to inform Ireland's emerging digital literacy and STEM education strategies, illustrating how national aspirations for digital literacy can be realised through play-based, developmentally appropriate approaches. Collectively, these contributions advance the scholarly discourse on early childhood computational thinking, while offering actionable frameworks to guide educators, researchers, and policymakers in shaping the future of digital learning in ECEC.

## 6.7 Final Reflection

As this study draws to a close, it is necessary to step back from the specific frameworks and findings to reflect on the unfolding story of the research. While the primary aim was to investigate the facilitating conditions for computational thinking (CT) in an Irish ECEC context, the process revealed a narrative that extends beyond the integration of a specific technology. What began as an inquiry into the use of programmable robotic kits evolved into a deeper exploration of educator identity, agency, and the complex ecology of professional learning. Throughout this design-based research, my positionality as a researcher-mentor allowed me to observe firsthand the tension between external policy expectations and the internal values of the educator. Therefore, this final section offers a reflective synthesis of how the Professional Learning Ecology Model emerged not just as a theoretical construct, but as a lived experience for both the participants and me.

### *6.7.1 Researcher Reflection*

This study has represented a period of significant personal and professional learning and development. My interest in computational thinking (CT) and programmable robotic kits (PRK) arose from the tensions I experienced about the use of digital technologies in early childhood, both as an early childhood educator and as a parent. Entering this research, I therefore shared many of the same questions and uncertainties as the participating educators, which shaped my empathy for their experiences and my commitment to finding ways that digital technologies could be integrated into early childhood education and care (ECEC) meaningfully. Engaging with the theoretical perspectives of constructionism, sociocultural learning, and ECEC professional knowledge was pivotal in reshaping my understanding of educator learning. Papert's constructionism, in particular, became central to how I came to think about the research process itself. His idea of "object to think with" offered not only a way to understand how children learn through tangible engagement but also a lens for my own meaning-making as a researcher. The educators' evolving understandings became my objects to think with, helping me reflect on how knowledge and pedagogy develop through dialogue, experimentation, and shared inquiry. In parallel, the children's thinking with mTiny became the educators' objects to think with, revealing the reciprocal nature of learning that constructionism so powerfully describes. Sociocultural perspectives further illuminated learning as inherently relational, while Campbell-Barr's (2019) conception of ECEC professional knowledge encouraged me to move beyond my initial assumptions regarding educators' digital competence. I came to recognise that their practice was not resistant but deeply grounded in relational, value-based pedagogy. Seeing this helped me reframe educators' approaches to digital technologies as expressions of professional care, collaboration, and agency, rather than as gaps to be remedied.

Conducting research situated in practice reinforced the importance of amplifying educators' voices within digital literacy and STEM discourse. Much of the research on CT and PRK

focuses on children's outcomes, overlooking the relational and contextual nature of early learning. This study affirmed that collaborative, practice-embedded research is essential if digital learning is to remain connected to the principles of play, wellbeing, and inclusion that underpin ECEC. Praxis, reflective, situated, and value-driven action, must continue to guide how we approach digital pedagogy.

The interpretive nature of the research was both challenging and rewarding. The richness of the data meant that new meanings emerged with each reading, and developing confidence in articulating this complexity became part of my own professional learning. I learned to use the theoretical and conceptual frameworks as an anchor, providing the discipline needed to stay close to the research focus while still honouring the nuances of lived experience. This process strengthened my belief that rich qualitative evidence is essential for shaping effective professional learning and policy in ECEC. The professional learning ecology (Figure 41) I present in this thesis also mirrors my own experience as a Doctor of Education student. I engaged in a form of scaffolded inquiry in which one supervisor brought a constructionist lens and the other an ECEC lens; together, their guidance created a supervisory environment that reflected the same dialogic, exploratory, and practice-focused learning processes and supports advocated for educators in this study.

Finally, this study has influenced my ongoing identity as a lecturer and researcher. It has clarified my emerging research agenda centred on ECEC professional learning, digital literacy, computational thinking, and co-designed inquiry. As Chair of the Early Childhood STEAM Network, I hope to build on this work through partnerships that connect research, practice, and community, supporting educators to explore digital learning in ways that remain grounded in play, reflection, and relational pedagogy. In this way, my personal and professional learning not only shaped the study but also guided the interpretations, methodological decisions, and meanings that ultimately emerged from it.

### *6.7.2 Concluding Statement*

This thesis set out to explore how early childhood educators, working within an evolving Irish ECEC and digital literacy landscape, can be supported to co-design purposeful robotic play experiences that foster young children's computational thinking (CT). Across the three themes, Computational Thinking Co-learners, Collaborative Inquiry, and Balancing Choice and Challenge, the study has illustrated that educators' professional learning for designing CT learning experiences is a relational and ecological process. Through this ecological lens, the thesis points to three key insights. First, it demonstrates that CT can be meaningfully and developmentally embedded within play-based, child-centred ECEC when educators are supported to participate as co-designers of purposeful robotic play. Second, it conceptualises a professional learning ecology that explains how educators' knowing what, knowing how, and knowing why evolve together in practice. Third, it illustrates that CT pedagogy in ECEC is best understood not as the introduction of a set of skills or tools, but as something that is shaped by the possibilities of the digital tools, educators' knowledge, practices and values, and children's interests and funds of knowledge. These insights carry particular weight in the Irish policy context, where early childhood digital literacy, STEM education are receiving increased attention, even though CT in ECEC is not yet mentioned in policy. The study provides evidence that CT and PRK can be enacted in ways that align with Aistear's (NCCA, 2024) emphasis on play, relationships, and children's and educators' agency, while also responding to emerging expectations around digital learning and providing a bridge from home to preschool to being a digital learner in primary school. At a time when Irish policy is asking how digital technologies and digital literacy should feature in early childhood, this study offers an account of what it looks like in practice, with CT as an appropriate way to foster young children's digital literacy. Across the study, CT emerged as an area of learning that could be woven into existing play-based, relational pedagogy when the right kinds of support were in place. Purposeful CT pedagogy in ECEC depends on

investment in practice-embedded, collaborative professional learning that values educators' existing professional knowledge and supports them to experiment, reflect, and re-think practice over time. It requires that digital tools such as PRK are accessible, age-appropriate, and used in everyday practice as part of intentional interactions where educators and children can explore together. Without these supports, there is a risk that the potential of CT to contribute to the development of digital literacy in ECEC will be overlooked in ongoing policy and practice.

Ultimately, this thesis argues for a view of educators as agentic co-learners and designers embedding meaningful and playful CT experiences for young children within their everyday practice.

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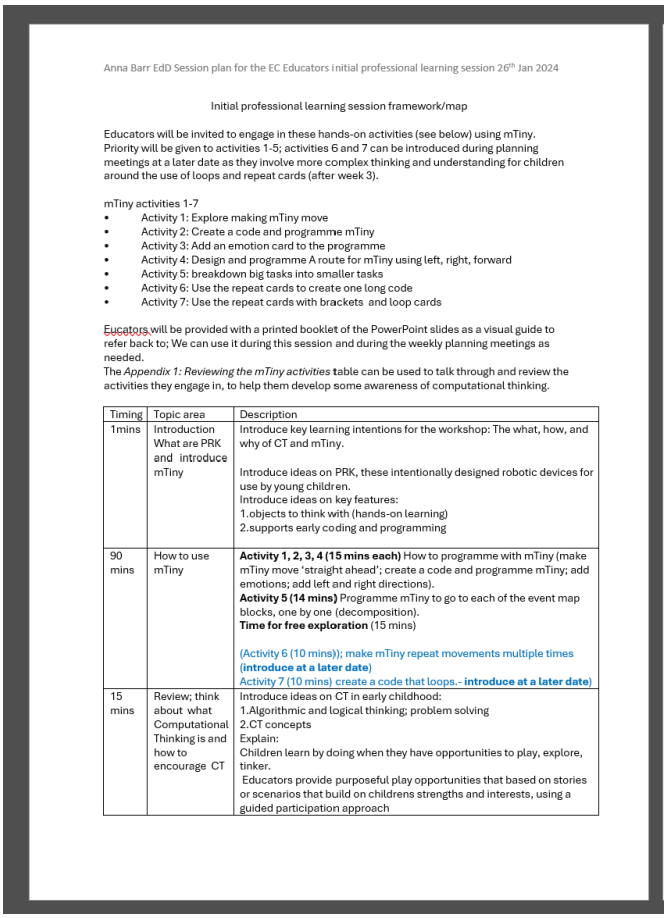
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# Appendix A: Educator Workshop Plan and Slides



Anna Barr EdD Session plan for the EC Educators initial professional learning session 26th Jan 2024

Initial professional learning session framework/map

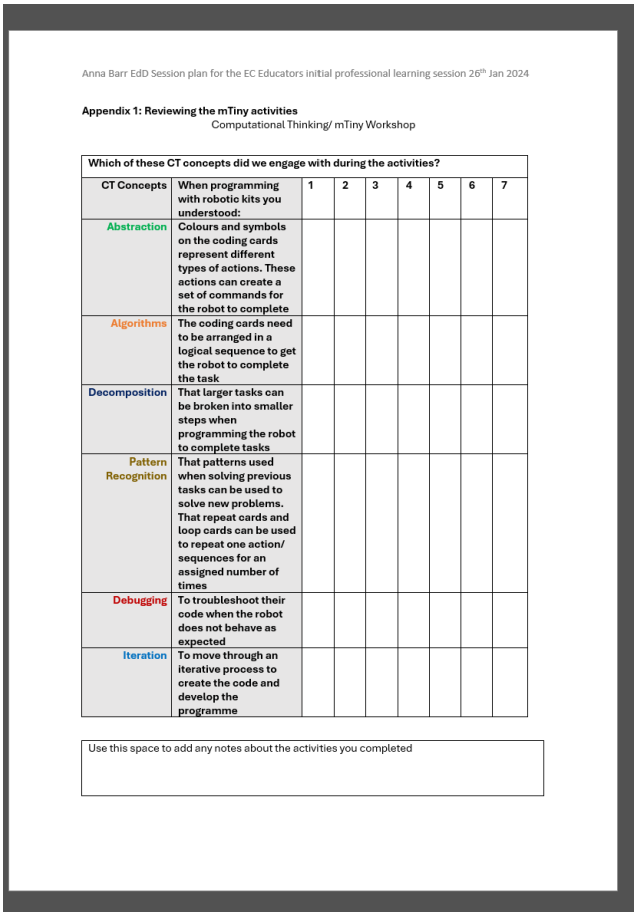
Educators will be invited to engage in these hands-on activities (see below) using mTiny. Priority will be given to activities 1-5; activities 6 and 7 can be introduced during planning meetings at a later date as they involve more complex thinking and understanding for children around the use of loops and repeat cards (after week 3).

mTiny activities 1-7

- Activity 1: Explore making mTiny move
- Activity 2: Create a code and programme mTiny
- Activity 3: Add an emotion card to the programme
- Activity 4: Design and programme A route for mTiny using left, right, forward
- Activity 5: breakdown big tasks into smaller tasks
- Activity 6: Use the repeat cards to create one long code
- Activity 7: Use the repeat cards with brackets and loop cards

Eucators will be provided with a printed booklet of the PowerPoint slides as a visual guide to refer back to; We can use it during this session and during the weekly planning meetings as needed.
The *Appendix 1: Reviewing the mTiny activities* table can be used to talk through and review the activities they engage in, to help them develop some awareness of computational thinking.

| Timing | Topic area | Description |
|---|---|---|
| 1mins | Introduction What are PRK and introduce mTiny | Introduce key learning intentions for the workshop: The what, how, and why of CT and mTiny.<br><br>Introduce ideas on PRK, these intentionally designed robotic devices for use by young children.<br>Introduce ideas on key features:<br>1.objects to think with (hands-on learning)<br>2.supports early coding and programming |
| 90 mins | How to use mTiny | **Activity 1, 2, 3, 4 (15 mins each)** How to programme with mTiny (make mTiny move 'straight ahead'; create a code and programme mTiny; add emotions; add left and right directions).<br>**Activity 5 (14 mins)** Programme mTiny to go to each of the event map blocks, one by one (decomposition).<br>**Time for free exploration** (15 mins)<br><br>(Activity 6 (10 mins)); make mTiny repeat movements multiple times (**introduce at a later date**)<br>Activity 7 (10 mins) create a code that loops.- **introduce at a later date**) |
| 15 mins | Review; think about what Computational Thinking is and how to encourage CT | Introduce ideas on CT in early childhood:<br>1.Algorithmic and logical thinking; problem solving<br>2.CT concepts<br>Explain:<br>Children learn by doing when they have opportunities to play, explore, tinker.<br>Educators provide purposeful play opportunities that based on stories or scenarios that build on childrens strengths and interests, using a guided participation approach |

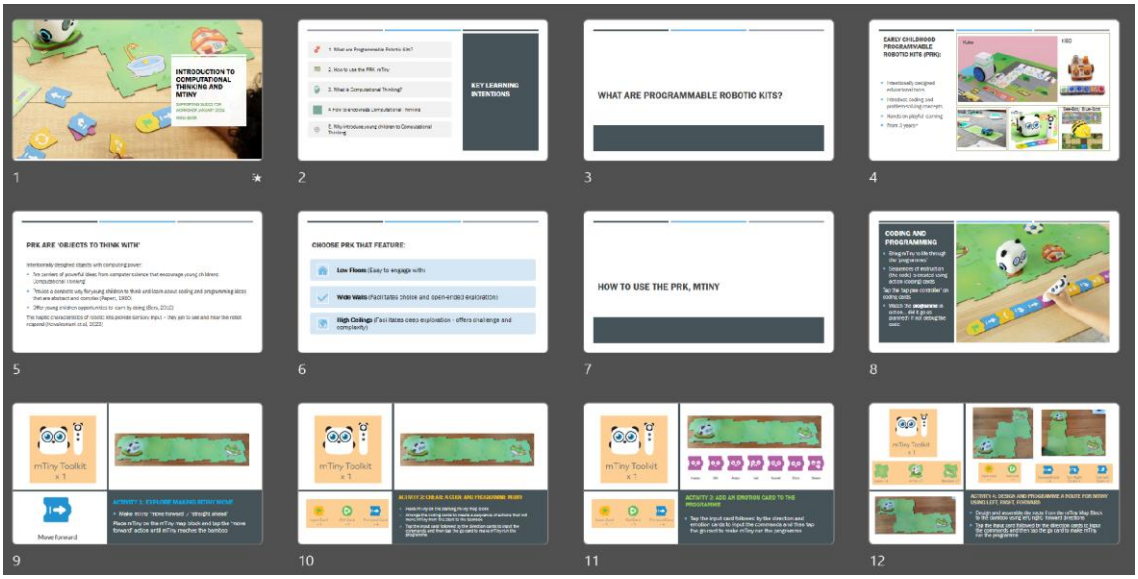


Anna Barr EdD Session plan for the EC Educators initial professional learning session 26th Jan 2024

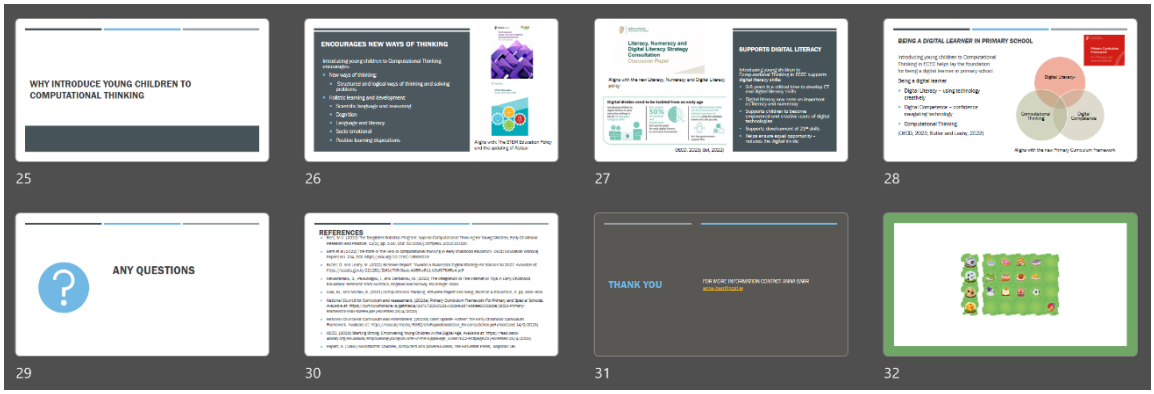
**Appendix 1: Reviewing the mTiny activities**
Computational Thinking/ mTiny Workshop

| **Which of these CT concepts did we engage with during the activities?** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **CT Concepts** | **When programming with robotic kits you understood:** | **1** | **2** | **3** | **4** | **5** | **6** | **7** |
| **Abstraction** | **Colours and symbols on the coding cards represent different types of actions. These actions can create a set of commands for the robot to complete** | | | | | | | |
| **Algorithms** | **The coding cards need to be arranged in a logical sequence to get the robot to complete the task** | | | | | | | |
| **Decomposition** | **That larger tasks can be broken into smaller steps when programming the robot to complete tasks** | | | | | | | |
| **Pattern Recognition** | **That patterns used when solving previous tasks can be used to solve new problems. That repeat cards and loop cards can be used to repeat one action/ sequences for an assigned number of times** | | | | | | | |
| **Debugging** | **To troubleshoot their code when the robot does not behave as expected** | | | | | | | |
| **Iteration** | **To move through an iterative process to create the code and develop the programme** | | | | | | | |

| Use this space to add any notes about the activities you completed |
|---|
| |


INTRODUCTION TO COMPUTATIONAL THINKING AND MTINY
KEY LEARNING INTENTIONS
WHAT ARE PROGRAMMABLE ROBOTIC KITS?
EARLY CHILDHOOD PROGRAMMABLE ROBOTIC KITS (PRK):
PRK ARE 'OBJECTS TO THINK WITH'
CHOOSE PRK THAT FEATURE:
HOW TO USE THE PRK, MTINY
CODING AND PROGRAMMING
mTiny Toolkit
1
2
3
4
5
6
7
8
9
10
11
12


CREATE SCENARIOS AND STORIES
TOWN MAP BLOCKS
WHAT IS COMPUTATIONAL THINKING (CT)?
COMPUTATIONAL THINKING
COMPUTATIONAL THINKING (CT) CONCEPTS
LETS REVIEW THE ACTIVITIES
HOW TO ENCOURAGE YOUNG CHILDREN'S COMPUTATIONAL THINKING
HOW CAN EC EDUCATORS SUPPORT YOUNG CHILDRENS CT
HOW CAN MTINY SUPPORT YOUNG CHILDRENS COMPUTATIONAL THINKING
Low Floors
Wide Walls
High Ceilings
13
14
15
16
17
18
19
20
21
22
23
24


WHY INTRODUCE YOUNG CHILDREN TO COMPUTATIONAL THINKING
ENCOURAGES NEW WAYS OF THINKING
SUPPORTS DIGITAL LITERACY
BEING A DIGITAL LEARNER IN PRIMARY SCHOOL
ANY QUESTIONS
REFERENCES
THANK YOU
25
26
27
28
29
30
31
32

# Appendix B: Co-design Intervention Dates

Anna Barr EdD Data collection/ intervention dates Jan 2024

**Individual interviews** with the EC educator participants to be completed the week of 22nd January.
We will need up to 1 hour per person; can take place on Zoom or in person.

**Workshop** with EC educator participants; this is a hands-on 1 hour workshop to introduce EC educators to mTiny; we will play and explore.

**Planning meetings** with Anna and the EC educators (6 in total): these will be 30 minute meetings to make plans for the next week of play sessions.

The **play sessions** with Anna, the EC educators and the children (12 in total): these will be 1 hour long play sessions with the mTiny robots.

The **debrief sessions** with Anna and the EC educators (12 in total): these will be 10 minute sessions to take place straight after to note what went well, what didn't go so well and what we noticed during the play session. Can be all of us together for 10 minutes or individual. This will support our planning.

**Final individual interviews** with the three EC educators to take place after the play sessions have finished. We can arrange dates that suit during the **week of 15th April or 22nd April**.

| Monday | Tuesday | Wednesday | Thursday | Friday |
|---|---|---|---|---|
| w/s 22nd Jan | 23rd Jan<br>3x interviews to take place this week,<br>days and times (TBC)<br>Interviews in person or Zoom | 24th Jan | 24th Jan | 26th Jan<br>Workshop - 12-1pm |
| | | | | 2nd Feb<br>Planning Meeting 11-11:30 |
| | 6th Feb<br>Play session 1: 9:30-10:30<br>Debrief: 10:30 (10 mins) | | 8th Feb<br>Play session 2: 9:30-10:30<br>Debrief:10:30 (10 mins) | 9th Feb<br>Planning Meeting 2: 12-12:30pm |
| | 13th Feb<br>Play session 3: 9:30-10:30<br>Debrief: 10:30 (10 mins) | | 15th Feb<br>Play session 4: 9:30-10:30<br>Debrief: 10:30 (10 mins) | 16th Feb<br>Planning Meeting 3: 12-12:30pm |
| | 20th Feb<br>Play session 5: 9:30-10:30<br>Debrief: 10:30 (10 mins)) | | 22nd Feb<br>Play session 6: 9:30-10:30<br>Debrief: 10:30 (10 mins) | 23rd Feb<br>Planning Meeting 4: 12-12:30pm |
| | 27th Feb<br>Play session 7: 9:30-10:30<br>Debrief: 10:30 (10 mins) | | 29th Feb<br>Play session 8: 9:30-10:30<br>Debrief: 10:30 (10 mins) | 1st March<br>Planning Meeting 5: 12-12:30pm |
| | 5th March<br>Play session 9: 9:30-10:30<br>Debrief: 10:30 (10 mins) | | 7th March<br>Play session 10: 9:30-10:30<br>Debrief: 10:30 (10 mins) | 8th March<br>Planning Meeting 6: 12-12:30pm |
| | 12th March<br>Play session 11: 9:30-10:30<br>Debrief: 10:30 (10 mins) | | 14th March<br>Play session 12: 9:30-10:30<br>Debrief: 10:30 (10 mins) | |
| Final individual interviews, post intervention to take place week of 15th April or 22nd April TBC | | | | |

# Appendix C: Mapping of Interview Schedule to Research Objectives and Literature

| Interview Section & Themes | Interview Question Numbers | Alignment with Research Objectives (RO) | Key Theoretical Concepts & Literature Sources |
|---|---|---|---|
| **Context & Pedagogy** *(Background, qualifications, preferred teaching approaches, active learning)* | Q1, Q2, Q3 | **RO 2:** Understanding baseline beliefs & values regarding ECEC pedagogy; Higher order thinking. | **Pedagogical Knowledge:** Active/Participatory learning; Intentional pedagogy. *French & McKenna, 2022; NCCA, 2009; 2024; Hedges et al., 2011; Fleer, 2011; Vidal-Hall, Flewitt and Wyse, 2020.* |
| **Educator's Personal Digital Engagement** *(Personal use, digital literacy, attitudes toward tech in daily life)* | Q4 | **RO 4:** Identifying determinants/influencers of technology acceptance. | **UTUAT (Venkatesh et al., 2003):** Performance Expectancy (PE); Effort Expectancy (EE);<br><br>Digital Literacy *Grieshaber et al, 2021; EU Commission, 2015; The Council of the EU, 2015; DE, 2017a; 2020b; 2023 GoI, 2023; OECD, 2023; Barron, Kennedy Martin and Roberts, 2007; NCCA, 2009; 2024* |
| **Digital Technologies in ECEC** *(Experience with children, beliefs about benefits/challenges, types of tech)* | Q5, Q6 | **RO 2 & 3:** Baseline professional knowledge and values regarding DT in early years. | **Facilitating Conditions & Beliefs (Venkatesh et al., 2003):** Social Influence (SI);<br><br>Appropriateness of DT; Parental/Educator mediation. *Palaiologou, 2016; Blackwell et al., 2014; NCCA, 2009, 2024; French and McKenna, 2022* |
| **Robotics & Computational Thinking (CT)** *(Knowledge of programmable toys, understanding of CT concepts)* | Q7, Q8, Q9 | **RO 3:** Assessment of specific domain knowledge (CT & Robotics) prior to intervention. | **Content Knowledge:** Definition of CT; Role of robotics in play. *Bers et al., 2019, 2022; Butler and Leahy, 2022; Silvis et al, 2022; French & McKenna, 2022; OECD, 2023* |
| **Support & Professional Learning** *(Perceived needs, preferred CPD formats, barriers)* | Q10, Q11 | **RO 4:** Identifying elements to leverage for future professional learning programmes. | **Facilitating Conditions (FC) (Venkatesh et al., 2003):** Intrinsic vs. Extrinsic barriers; Mentoring needs. *(Ertmer, 1999; Blackwell et al., 2014; Stevenson et al., 2019 Barron, Kennedy Martin and Roberts, 2007; Johnston et al. 2020; Johnston, 2019; Van den Beemt and Diepstraten, 2016; Grieshaber et al. (2021)* |

# Appendix D: Final Interview Schedules



Semi-Structured Interview schedule for use with EC educator

Beginning the interview:

- Introductions
- Outline the purpose and structure of the interview.
- Ask for consent to record and to transcribe the interview.
- Opportunity to ask any questions before beginning.

Interview questions:

1. Can you tell me about your background and experience as an early childhood educator?
   Prompts
   i. How long you have been working in early childhood education and care (ECEC)?
   ii. What types of early childhood settings have you worked in?
   iii. Which age ranges of young children you have worked with?
   iv. Which ECEC qualifications have you completed, for example at Levels 5, 6,7 or 8?
   v. Are there any other professional learning opportunities or programmes you have engaged in?

2. Can you tell me about the teaching and learning approaches you prefer or tend to use when working with young children in early childhood education and care (ECEC)?
   Prompts
   i. Do you encourage active learning / hands-on learning/ learn by doing/ exploring and thinking?
   ii. Which types of play do you usually plan for; free play, guided play, structured play or a blend of all three?
   iii. Which roles do you regularly take on, for example, being an observer, being a facilitator, scaffolding, leading the play, being a play partner, being a co-learner or co-creator with the children?
   iv. How do you usually plan for children's learning, for example would you create curriculum plans for the year, the month, week by week, or in response to the children's emerging interests?
   v. How often do you build on children's interests, strengths and experiences from home when planning learning experiences?
   vi. What curriculum approaches influence you, for example Montessori, Highscope or Reggio Emilia approaches, and/or following play based and emergent and inquiry curriculum approaches promoted by Aistear?

3. Can you tell me about some of the digital technologies you engage with as part of your daily life?
   Prompts
   i. How often do you use this technology?
   ii. What do you use this technology for?
   iii. What influenced you to start using this technology?
   iv. What do you think the benefits and challenges of using this technology are?
   v. How did you learn to use this technology?

4. Can you tell me about your experience of using digital technologies in your role as an early childhood educator?
   Prompts
   i. How often do/did you use this technology?
   ii. What do/did you use this technology for?
   iii. What influenced you to start using this technology?
   iv. What do you think the benefits and challenges of using this technology are/were for you, the setting, the children and their families?
   v. How did you learn to use this technology?

5. Can you tell me about your experience of using digital technologies with young children?
   Prompts
   i. Was this in your role as an early childhood educator, parent or other context?
   ii. How often do/did you use this technology?
   iii. What do/did you use this technology for?
   iv. What influenced you to start using this technology?
   v. What approach did you take with the child/children?
   vi. What do you think the benefits and challenges of using this technology are/were for you and the child/children?
   vii. How did you learn to use this technology?
   viii. If you have no experience using technology with children, can you tell me why not, for example is it because you had no opportunity, or were unsure how to use it and what approach to take, or is it because you don't agree with children using digital technologies or were there other challenges or reasons

6. Can you tell me about what you know about different types of digital technologies that young children use?
   Prompts
   i. Mobile touch screen devices such as phones or tablets
   ii. Robotic devices such as bee bots or mTiny
   iii. Screen based computers
   iv. AI speakers, for example Alexa or Google home speakers
   v. Digital microscopes or digital projectors
   vi. Can they enhance the learning experience for young children? How ?
   vii. What do think the benefits or challenges might be?
   viii. What considerations would need to be taken into account when selecting digital technologies for young children to use?

7. Can you tell me what you know and understand about robotic devices that have been designed for young children to programme and play with?
   Prompts
   i. What purpose do you think robotic devices designed for young children have?
   ii. What are some of the benefits or challenges of introducing robotic devices to young children?
   iii. What are some of the ways robotic kits can be used to support young children's learning?
   iv. How might robotic devices enhance young childrens learning experiences?

v. Do you think robotic devices have a role in preparing young children for the digital world we live in

8. Can you tell me what you know and understand about the term Computational Thinking?
   i. Have you heard of it before?
   ii. What do you think it might mean?

9. Can you tell me about the areas you feel you would need support with when using robotic devices with children in your role as an early childhood educator?
   Prompts
   i. Support with how to use the robotic kits
   ii. Support with how to assess the effectiveness of the robotic device for childrens learning
   iii. Support with strategies or best practices to support young children's learning
   iv. Support with how to enhance the learning experience for young children
   v. Support with how to ensure that the use of digital technology aligns with holistic learning and development and learning goals for young children
   vi. Support with how to integrate the experiences within a play-based approach
   vii. Support with identifying and understanding the ethical consideration

10. Can you tell me what types of continuous professional development (CPD) or support would be most useful to you?
    Prompts
    i. Online live webinars
    ii. Online pre-recorded guides
    iii. In person, hands-on workshops
    iv. Mentoring visits from a specialist to your early childhood setting to support practice
    v. A designated leader from your early childhood setting team to guide practice
    vi. A community of practice with early childhood educators from other EC settings who use digital technologies with children
    vii. Are there any other supports you think might be useful to you?

11. Is there anything you would like to add

End of interview:

- Ask the participant if there is anything to be clarified from the information given and if the researcher has permission to contact them again.
- Thank participants for taking part and giving their time to the research.

# Semi-Structured Interview schedule for use with EC educators

Beginning the interview:

- Outline the purpose and structure of the interview.
- Ask for consent to record and to transcribe the interview.
- Opportunity to ask any questions before beginning.

Interview questions

Q1. Looking back over the previous 6 weeks what are the key things that stand out to you?
Prompts: key highlights, key challenges, key points, key takeaways.

Q2. Do you think the children benefitted from playing with the mTiny robotic kits?
Prompts: If yes, how/in what way?; If no, why not?

Q3. Did you experience any difficulties when you were supporting the children's engagement with the mTiny robotic kits and their computational thinking?
Prompts: If yes, can you give examples/ how did you overcome them?

Q4. How useful were the different parts of the research project in preparing you to support the children's computational thinking and play with the mTiny robotic kits?
Prompts: -Parts: Workshop-play sessions- debriefs- planning meetings- co-design process; Amount and frequency- prefer more or less; Opportunities- to learn as you go, share ideas, plan, feedback, review and reflect.

Q5. Did participating in the research project and co-design process differ from your expectations?
Prompts: If yes, can you give examples; If no, tell me about your expectations

Q6. Did the play sessions help your understanding of computational thinking?
Prompt: If yes, how/ in what way?, were there any particular moments? If no, why not?

Q7. Do you feel confident supporting children's computational thinking compared with when you first started the co-design project?
Prompts: If yes, how/in what ways?; If no, why not?

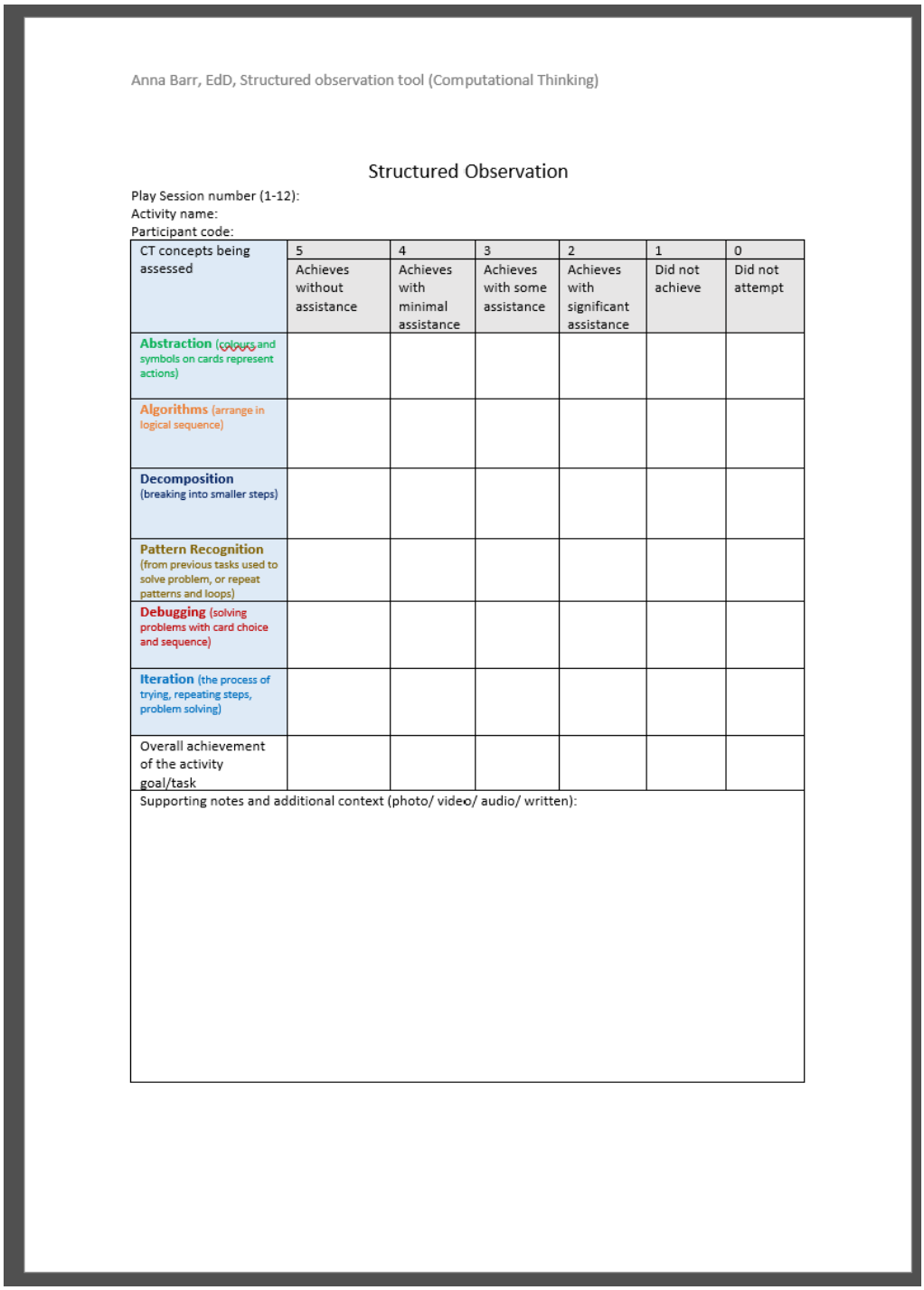
Q8. Do you feel confident supporting children's play with mTiny robotic kits compared to the beginning of the co-design project?
Prompts: If yes, how/in what way?; If no, why not?

Q9. Have you used the mTiny robotic kits with the children since finishing the 12 play sessions?
Prompts: If yes, tell me more about how it went; If no, why not?, What might change that?, Have the children asked to play with them?

Q10. Do you think you might share what you've learned about computational thinking and play with the mTiny robotic kits with other early childhood educators in your setting?
Prompts: If yes, can you tell me more; If no, why not?

Q11. Do you have any advice for me on the supports you think other early childhood educators might need to become confident and competent to lead play sessions with mTiny robotic kits and support children's computational thinking?
Prompts: If yes, can you give examples; If no, would they benefit from the same supports you had, or other supports?

# Appendix E: Structured Observation Template



Anna Barr, EdD, Structured observation tool (Computational Thinking)

Structured Observation

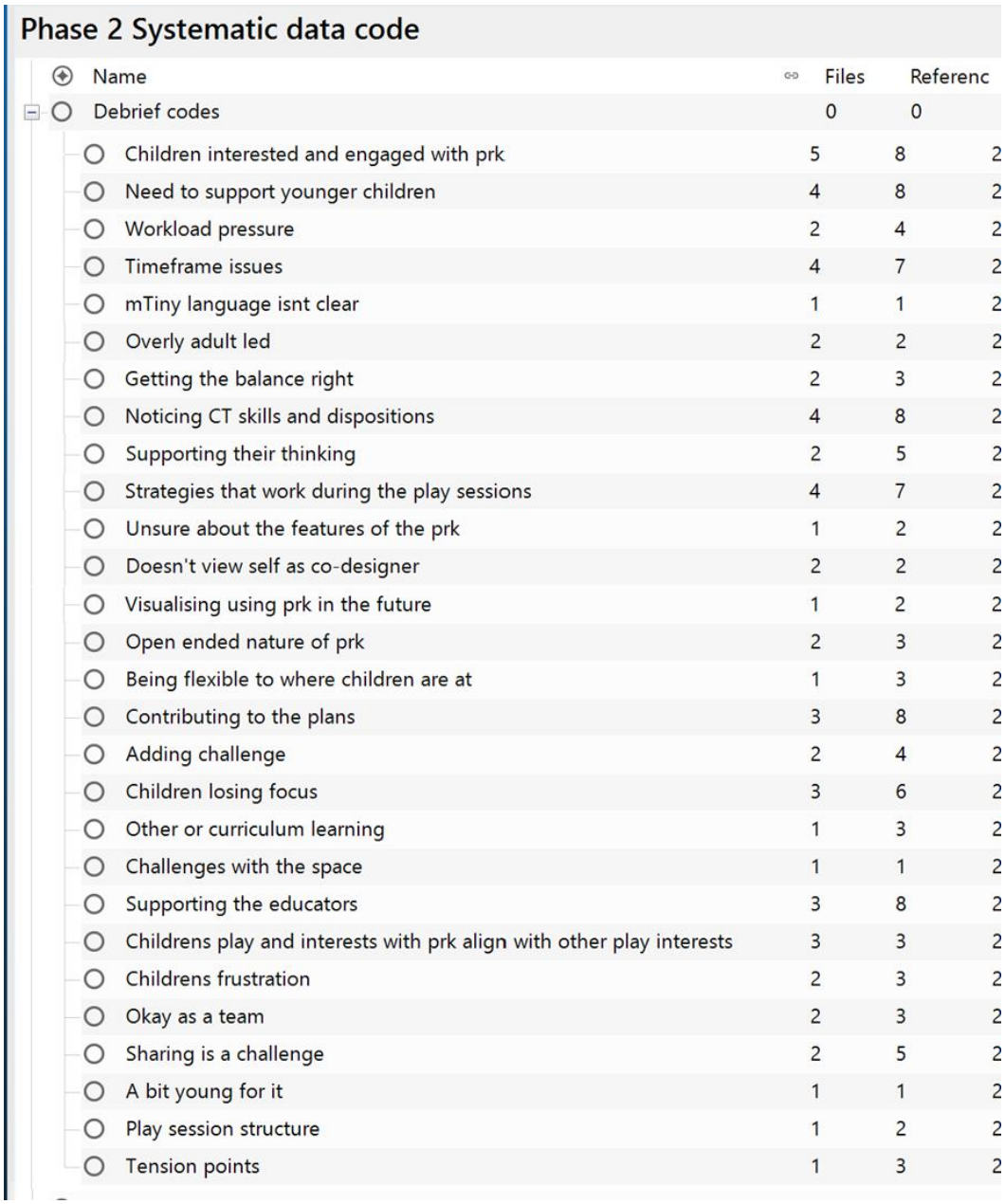
Play Session number (1-12):
Activity name:
Participant code:

| CT concepts being assessed | 5<br>Achieves without assistance | 4<br>Achieves with minimal assistance | 3<br>Achieves with some assistance | 2<br>Achieves with significant assistance | 1<br>Did not achieve | 0<br>Did not attempt |
|---|---|---|---|---|---|---|
| **Abstraction** (colours and symbols on cards represent actions) | | | | | | |
| **Algorithms** (arrange in logical sequence) | | | | | | |
| **Decomposition** (breaking into smaller steps) | | | | | | |
| **Pattern Recognition** (from previous tasks used to solve problem, or repeat patterns and loops) | | | | | | |
| **Debugging** (solving problems with card choice and sequence) | | | | | | |
| **Iteration** (the process of trying, repeating steps, problem solving) | | | | | | |
| Overall achievement of the activity goal/task | | | | | | |
| Supporting notes and additional context (photo/ video/ audio/ written): | | | | | | |

# Appendix F: Tracking Educators' learning and decision-making

| | Participant 1 Lead educator (LE) | Participant 2 Educator (ED) |
|---|---|---|
| Intervention Week 3 16th -22nd February<br><br>(Planning meeting 3, play sessions 5 (PS5) and PS6; debrief sessions 5 and 6) | **Planning for week 3 involved greater co-design input.** Originally was happy to agree with my ideas, however had hesitations, so I probed further and found we teased out and agreed something quite different (a less structured activity for PS5 so that children could bring their own ideas). **LE provided a lot of input.**<br><br>I noticed that LE was very engaged throughout the play sessions and debriefs. For example, she sought my thoughts on PS5 during the debrief, and was ready to raise what we needed to make decisions on (for example how splitting the 1 hour into 2x 30 min sessions was working).<br><br>LE was a lot more vocal during the play sessions this week, lots of verbal prompts and encouragement. She modelled thinking for children to encourage them to persevere. Her approach aligned with what we had agreed in previous debrief and planning- that we would increase our use of verbal strategies.<br><br>During PS6 I had time to observe LE and listen to some of her strategies to encourage thinking about the sequence of move forward and move left steps. She adapted her strategies to suit were different children were at; providing a lot of support- modelling thinking and actions, demonstrating, use of verbal prompts and encouraging perseverance.<br><br>I had the chance to ask her what approaches were working well and gave positive feedback and encouragement. I felt more like this was us learning together rather than me being the leader of 'how to do it'.<br><br>I feel there is a tension point for LE around how much or little structure or guidance the play sessions should have (although not as strong as how ED feels about this). | **Planning for week 3 involved greater co-design input.** Originally was happy to agree with my ideas, however, has hesitations, so I probed further and found we teased out and agreed something quite different (a less structured activity for PS5 so that children could bring their own ideas). **ED provided less input and tended to agree with LE** (although she has definite ideas and views of her own).<br><br>ED was a lot more vocal during the play sessions this week, lots of verbal prompts and encouragement. She modelled thinking for children to encourage them to persevere. Her approach aligned with what we had agreed in previous debrief and planning- that we would increase our use of verbal strategies.<br><br>During PS6 I had time to observe ED and listen to some of her strategies to encourage thinking about the sequence of move forward and move left steps. I had the chance to ask her what approaches were working well and gave positive feedback and encouragement.<br><br>She noticed that during the PS5 small group exploration (which was more child-led ) that is was challenging for the children to concentrate and persevere. Whereas during PS6 (which was more educator led) she noticed that the children were more focused and making connections between the coding cards and sequence/ steps mTiny made. Although she did not acknowledge or comment on the differences when we take different approaches. I feel there is a tension point around how much or little structure or guidance the play sessions should have; ED has advocated for children doing things their way since the beginning, and has raised concerns with being too structured. |

# Appendix G: Phase Two Analysis: example of initial codes



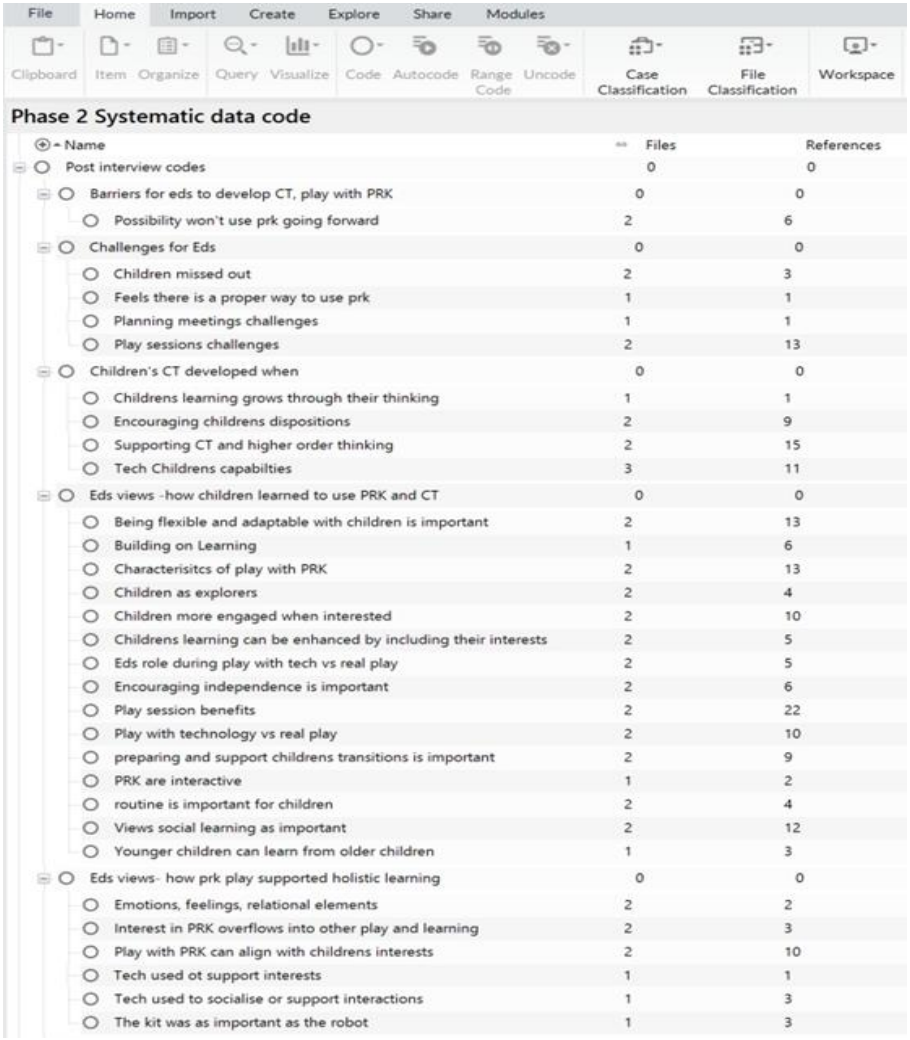
**Phase 2 Systematic data code**

| Name | Files | Referenc | |
|---|---|---|---|
| Debrief codes | 0 | 0 | |
| Children interested and engaged with prk | 5 | 8 | 2 |
| Need to support younger children | 4 | 8 | 2 |
| Workload pressure | 2 | 4 | 2 |
| Timeframe issues | 4 | 7 | 2 |
| mTiny language isnt clear | 1 | 1 | 2 |
| Overly adult led | 2 | 2 | 2 |
| Getting the balance right | 2 | 3 | 2 |
| Noticing CT skills and dispositions | 4 | 8 | 2 |
| Supporting their thinking | 2 | 5 | 2 |
| Strategies that work during the play sessions | 4 | 7 | 2 |
| Unsure about the features of the prk | 1 | 2 | 2 |
| Doesn't view self as co-designer | 2 | 2 | 2 |
| Visualising using prk in the future | 1 | 2 | 2 |
| Open ended nature of prk | 2 | 3 | 2 |
| Being flexible to where children are at | 1 | 3 | 2 |
| Contributing to the plans | 3 | 8 | 2 |
| Adding challenge | 2 | 4 | 2 |
| Children losing focus | 3 | 6 | 2 |
| Other or curriculum learning | 1 | 3 | 2 |
| Challenges with the space | 1 | 1 | 2 |
| Supporting the educators | 3 | 8 | 2 |
| Childrens play and interests with prk align with other play interests | 3 | 3 | 2 |
| Childrens frustration | 2 | 3 | 2 |
| Okay as a team | 2 | 3 | 2 |
| Sharing is a challenge | 2 | 5 | 2 |
| A bit young for it | 1 | 1 | 2 |
| Play session structure | 1 | 2 | 2 |
| Tension points | 1 | 3 | 2 |

# Appendix H: Phase Two Analysis: code labels

(a) example of codes grouped under broader code labels within NVivo and (b) grouped as a booklet

## (a) NVivo

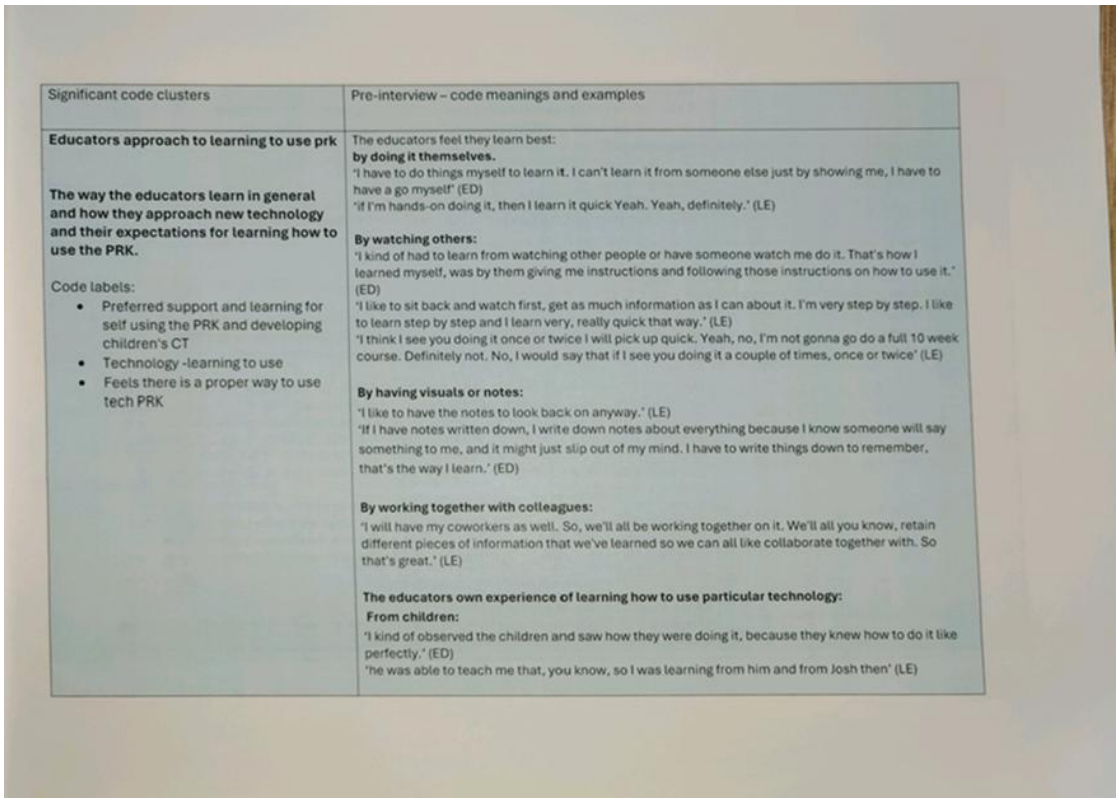



**Phase 2 Systematic data code**

| Name | Files | References |
|---|---|---|
| Post interview codes | 0 | 0 |
| Barriers for eds to develop CT, play with PRK | 0 | 0 |
| Possibility won't use prk going forward | 2 | 6 |
| Challenges for Eds | 0 | 0 |
| Children missed out | 2 | 3 |
| Feels there is a proper way to use prk | 1 | 1 |
| Planning meetings challenges | 1 | 1 |
| Play sessions challenges | 2 | 13 |
| Children's CT developed when | 0 | 0 |
| Childrens learning grows through their thinking | 1 | 1 |
| Encouraging childrens dispositions | 2 | 9 |
| Supporting CT and higher order thinking | 2 | 15 |
| Tech Childrens capabilties | 3 | 11 |
| Eds views -how children learned to use PRK and CT | 0 | 0 |
| Being flexible and adaptable with children is important | 2 | 13 |
| Building on Learning | 1 | 6 |
| Characterisitcs of play with PRK | 2 | 13 |
| Children as explorers | 2 | 4 |
| Children more engaged when interested | 2 | 10 |
| Childrens learning can be enhanced by including their interests | 2 | 5 |
| Eds role during play with tech vs real play | 2 | 5 |
| Encouraging independence is important | 2 | 6 |
| Play session benefits | 2 | 22 |
| Play with technology vs real play | 2 | 10 |
| preparing and support childrens transitions is important | 2 | 9 |
| PRK are interactive | 1 | 2 |
| routine is important for children | 2 | 4 |
| Views social learning as important | 2 | 12 |
| Younger children can learn from older children | 1 | 3 |
| Eds views- how prk play supported holistic learning | 0 | 0 |
| Emotions, feelings, relational elements | 2 | 2 |
| Interest in PRK overflows into other play and learning | 2 | 3 |
| Play with PRK can align with childrens interests | 2 | 10 |
| Tech used ot support interests | 1 | 1 |
| Tech used to socialise or support interactions | 1 | 3 |
| The kit was as important as the robot | 1 | 3 |

| Name | Files | References |
|---|---|---|
| Eds views- valuable approaches to suuport children's learning | 0 | 0 |
| Observing children supports planning | 2 | 3 |
| Planning for childrens learning needs short and long term | 2 | 8 |
| Preferred curriculum approaches | 2 | 6 |
| Purposeful learning experiences are beneficial | 1 | 1 |
| Tech the relevance for young children in EC | 2 | 4 |
| not using these codes | 0 | 0 |
| Change in perspective | 2 | 7 |
| Curious to understand how things work and how to | 2 | 4 |
| Professional learning | 2 | 22 |
| Tech concerns | 1 | 3 |
| Tech drawbacks | 2 | 4 |
| Understanding DT | 2 | 4 |
| Whar eds learned about CT for 3-5yr olds | 0 | 0 |
| Eds Understanding of CT | 2 | 17 |
| What might influence the eds to continue | 0 | 0 |
| Confidence with PRK | 2 | 14 |
| Experiences with robotic kits | 2 | 20 |
| Open to play with PRK | 2 | 18 |
| Tech aware children are interested in it | 2 | 5 |
| What supported eds to develop CT-play with PRK | 0 | 0 |
| Being more familar with PRK and CT supported childrens participati | 1 | 2 |
| Children and educators learned from each other or together | 2 | 15 |
| Eds learning to use the PRK | 2 | 17 |
| Educators being on the same page | 2 | 6 |
| Feeling overwhelmed | 2 | 10 |
| Figuring it out how things work comes first | 1 | 4 |
| Learning as we went | 1 | 11 |
| Planning meetings benefits | 2 | 11 |
| Preferred support and learning for self using prk | 1 | 17 |
| Tech Experience with young childrens use of | 2 | 5 |

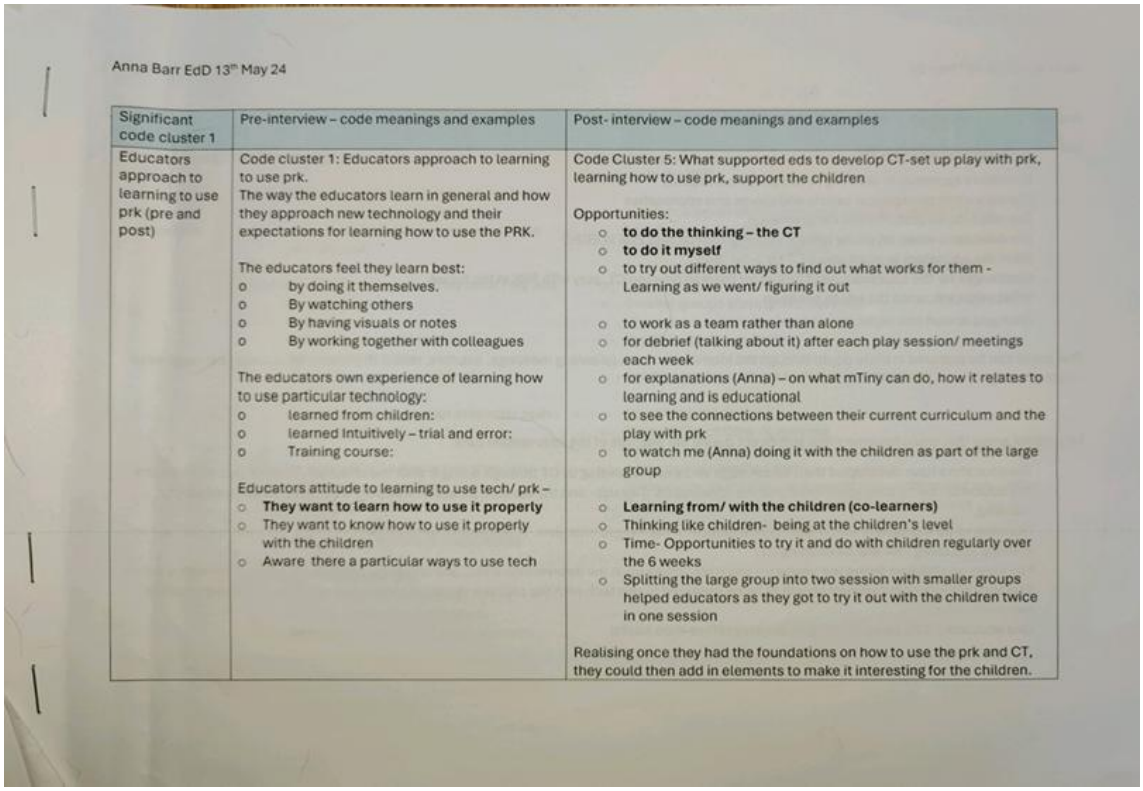
## (b) Booklet



| Significant code clusters | Pre-interview – code meanings and examples |
|---|---|
| **Educators approach to learning to use prk**<br><br>**The way the educators learn in general and how they approach new technology and their expectations for learning how to use the PRK.**<br><br>Code labels:<br>• Preferred support and learning for self using the PRK and developing children's CT<br>• Technology -learning to use<br>• Feels there is a proper way to use tech PRK | The educators feel they learn best:<br>**by doing it themselves.**<br>'I have to do things myself to learn it. I can't learn it from someone else just by showing me, I have to have a go myself' (ED)<br>'if I'm hands-on doing it, then I learn it quick Yeah. Yeah, definitely.' (LE)<br><br>**By watching others:**<br>'I kind of had to learn from watching other people or have someone watch me do it. That's how I learned myself, was by them giving me instructions and following those instructions on how to use it.' (ED)<br>'I like to sit back and watch first, get as much information as I can about it. I'm very step by step. I like to learn step by step and I learn very, really quick that way.' (LE)<br>'I think I see you doing it once or twice I will pick up quick. Yeah, no, I'm not gonna go do a full 10 week course. Definitely not. No, I would say that if I see you doing it a couple of times, once or twice' (LE)<br><br>**By having visuals or notes:**<br>'I like to have the notes to look back on anyway.' (LE)<br>'If I have notes written down, I write down notes about everything because I know someone will say something to me, and it might just slip out of my mind. I have to write things down to remember, that's the way I learn.' (ED)<br><br>**By working together with colleagues:**<br>'I will have my coworkers as well. So, we'll all be working together on it. We'll all you know, retain different pieces of information that we've learned so we can all like collaborate together with. So that's great.' (LE)<br><br>**The educators own experience of learning how to use particular technology:**<br>**From children:**<br>'I kind of observed the children and saw how they were doing it, because they knew how to do it like perfectly.' (ED)<br>'he was able to teach me that, you know, so I was learning from him and from Josh then' (LE) |

# Appendix I: Phase Three Analysis: Initial Themes

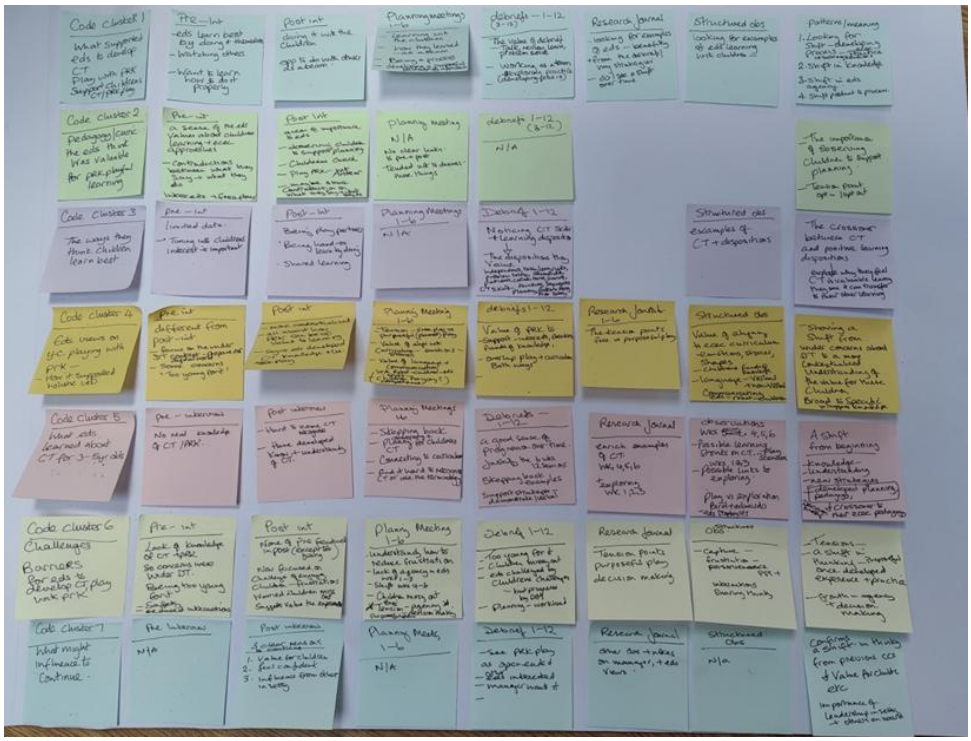
## (a) Pre and post interview clusters analysis booklet



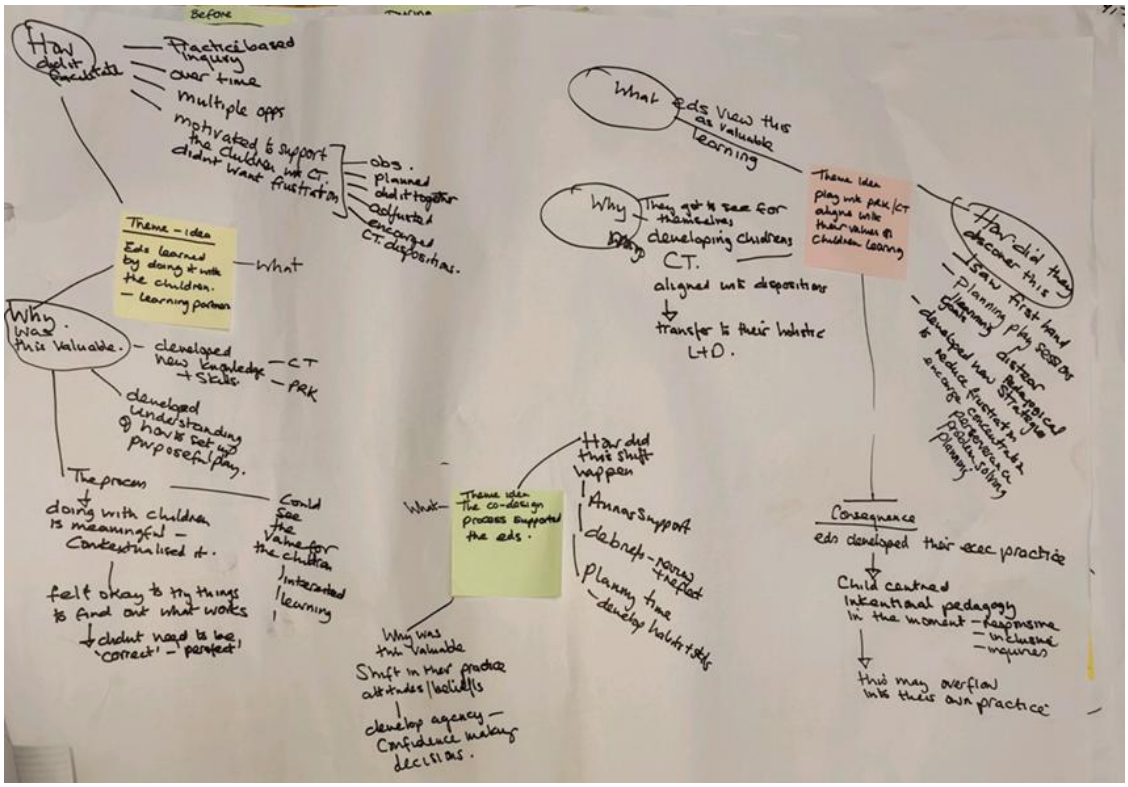
Anna Barr EdD 13th May 24

| Significant code cluster 1 | Pre-interview – code meanings and examples | Post- interview – code meanings and examples |
|---|---|---|
| Educators approach to learning to use prk (pre and post) | Code cluster 1: Educators approach to learning to use prk.<br>The way the educators learn in general and how they approach new technology and their expectations for learning how to use the PRK.<br><br>The educators feel they learn best:<br>o by doing it themselves.<br>o By watching others<br>o By having visuals or notes<br>o By working together with colleagues<br><br>The educators own experience of learning how to use particular technology:<br>o learned from children:<br>o learned Intuitively – trial and error:<br>o Training course:<br><br>Educators attitude to learning to use tech/ prk –<br>o **They want to learn how to use it properly**<br>o They want to know how to use it properly with the children<br>o Aware there a particular ways to use tech | Code Cluster 5: What supported eds to develop CT-set up play with prk, learning how to use prk, support the children<br><br>Opportunities:<br>o **to do the thinking – the CT**<br>o **to do it myself**<br>o to try out different ways to find out what works for them - Learning as we went/ figuring it out<br><br>o to work as a team rather than alone<br>o for debrief (talking about it) after each play session/ meetings each week<br>o for explanations (Anna) – on what mTiny can do, how it relates to learning and is educational<br>o to see the connections between their current curriculum and the play with prk<br>o to watch me (Anna) doing it with the children as part of the large group<br><br>o **Learning from/ with the children (co-learners)**<br>o Thinking like children- being at the children's level<br>o Time- Opportunities to try it and do with children regularly over the 6 weeks<br>o Splitting the large group into two session with smaller groups helped educators as they got to try it out with the children twice in one session<br><br>Realising once they had the foundations on how to use the prk and CT, they could then add in elements to make it interesting for the children. |

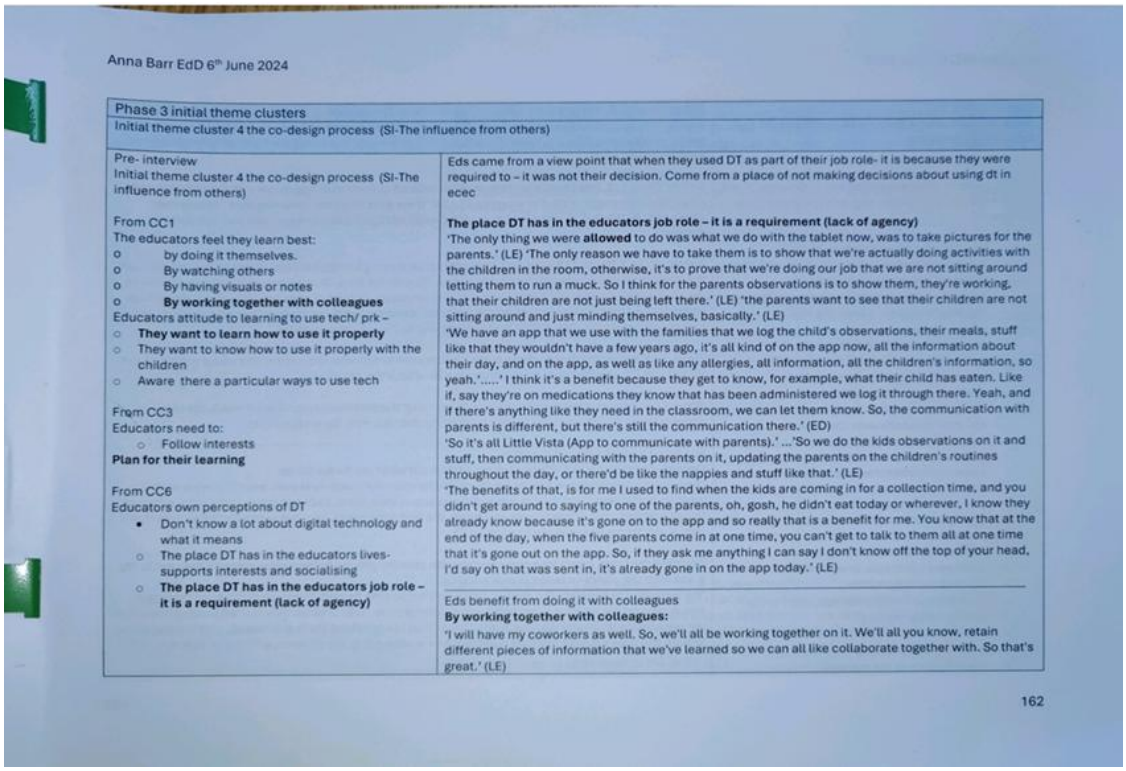
## (b) Looking for significant patterns across the seven coding clusters in relation to the research question.



## (c) Mapping initial theme ideas in relation to the seven clusters




## (d) Initial theme cluster booklets



Anna Barr EdD 6th June 2024

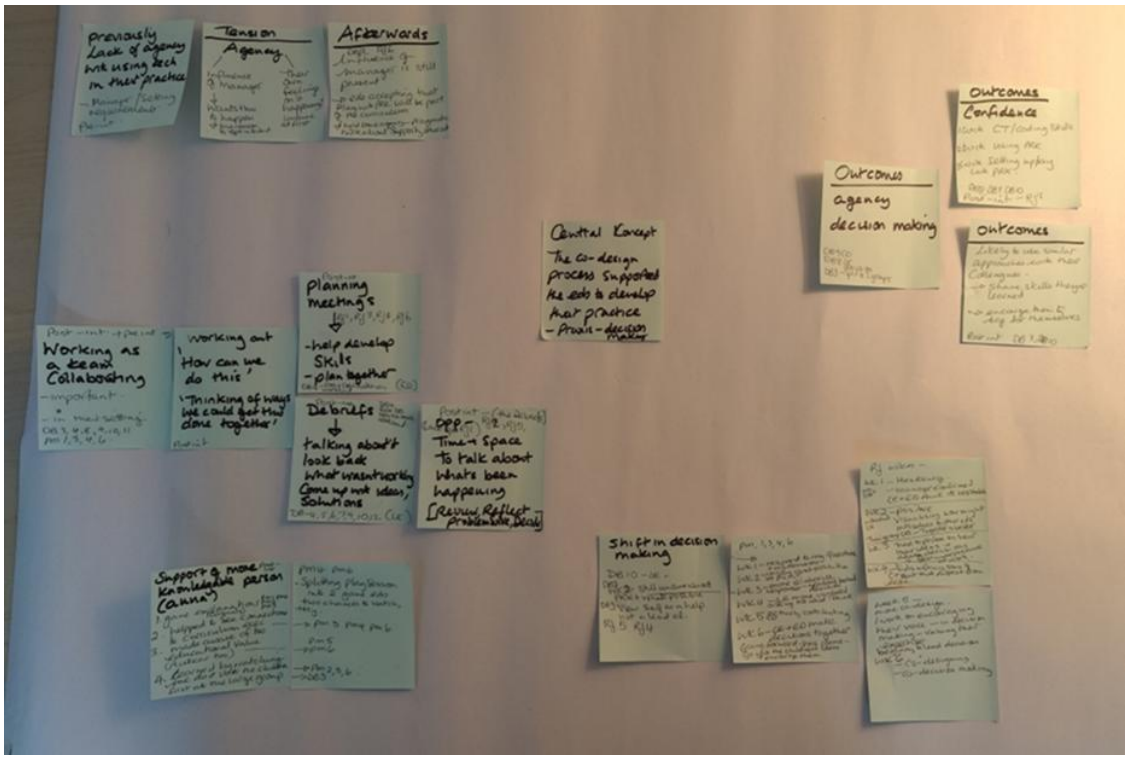
**Phase 3 initial theme clusters**

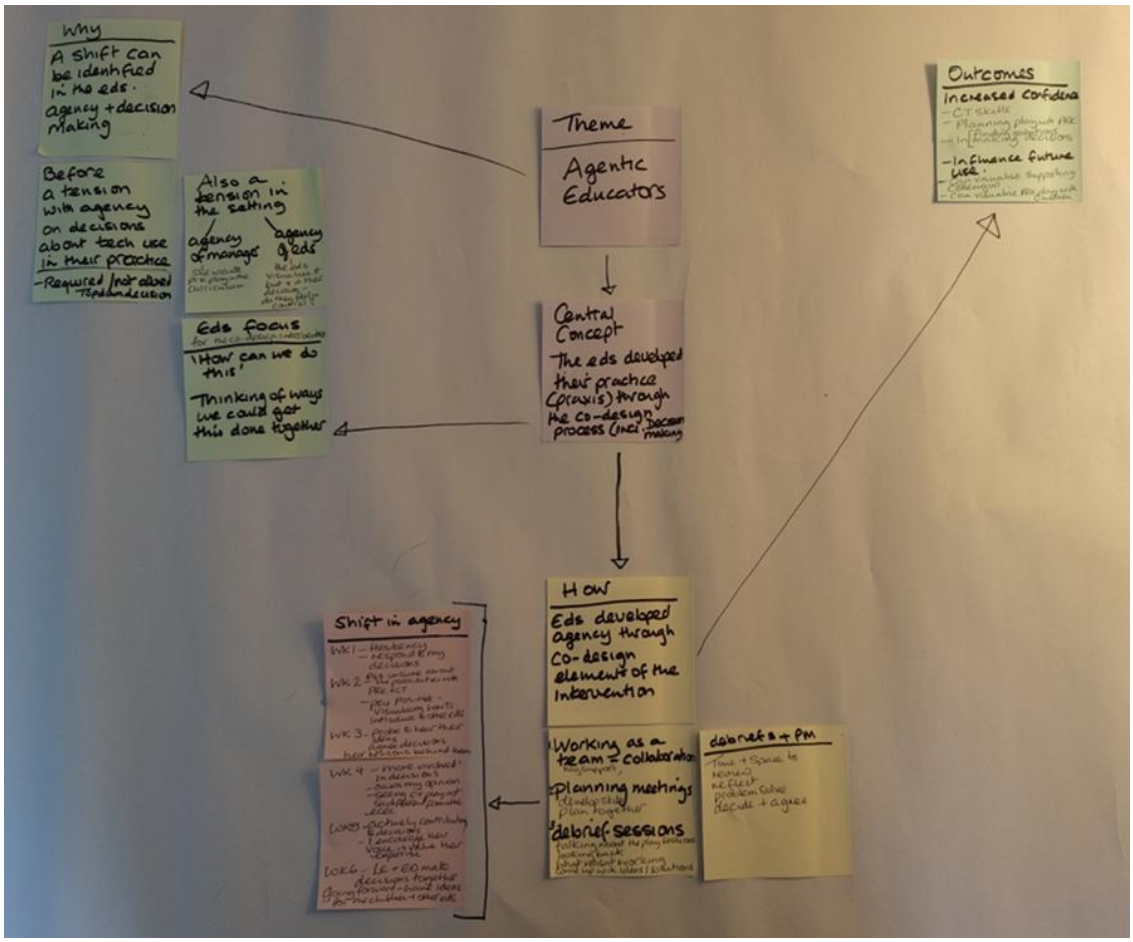
**Initial theme cluster 4 the co-design process (SI-The influence from others)**

| | |
|---|---|
| Pre- interview<br>Initial theme cluster 4 the co-design process (SI-The influence from others)<br><br>From CC1<br>The educators feel they learn best:<br>o by doing it themselves.<br>o By watching others<br>o By having visuals or notes<br>o **By working together with colleagues**<br>Educators attitude to learning to use tech/ prk –<br>○ **They want to learn how to use it properly**<br>○ They want to know how to use it properly with the children<br>○ Aware there a particular ways to use tech<br><br>From CC3<br>Educators need to:<br>○ Follow interests<br>**Plan for their learning**<br><br>From CC6<br>Educators own perceptions of DT<br>• Don't know a lot about digital technology and what it means<br>○ The place DT has in the educators lives- supports interests and socialising<br>○ **The place DT has in the educators job role – it is a requirement (lack of agency)** | Eds came from a view point that when they used DT as part of their job role- it is because they were required to – it was not their decision. Come from a place of not making decisions about using dt in ecec<br><br>**The place DT has in the educators job role – it is a requirement (lack of agency)**<br>'The only thing we were **allowed** to do was what we do with the tablet now, was to take pictures for the parents.' (LE) 'The only reason we have to take them is to show that we're actually doing activities with the children in the room, otherwise, it's to prove that we're doing our job that we are not sitting around letting them to run a muck. So I think for the parents observations is to show them, they're working, that their children are not just being left there.' (LE) 'the parents want to see that their children are not sitting around and just minding themselves, basically.' (LE)<br>'We have an app that we use with the families that we log the child's observations, their meals, stuff like that they wouldn't have a few years ago, it's all kind of on the app now, all the information about their day, and on the app, as well as like any allergies, all information, all the children's information, so yeah.'.....' I think it's a benefit because they get to know, for example, what their child has eaten. Like if, say they're on medications they know that has been administered we log it through there. Yeah, and if there's anything like they need in the classroom, we can let them know. So, the communication with parents is different, but there's still the communication there.' (ED)<br>'So it's all Little Vista (App to communicate with parents).' ...'So we do the kids observations on it and stuff, then communicating with the parents on it, updating the parents on the children's routines throughout the day, or there'd be like the nappies and stuff like that.' (LE)<br>'The benefits of that, is for me I used to find when the kids are coming in for a collection time, and you didn't get around to saying to one of the parents, oh, gosh, he didn't eat today or wherever, I know they already know because it's gone on to the app and so really that is a benefit for me. You know that at the end of the day, when the five parents come in at one time, you can't get to talk to them all at one time that it's gone out on the app. So, if they ask me anything I can say I don't know off the top of your head, I'd say oh that was sent in, it's already gone in on the app today.' (LE)<br><br>Eds benefit from doing it with colleagues<br>**By working together with colleagues:**<br>'I will have my coworkers as well. So, we'll all be working together on it. We'll all you know, retain different pieces of information that we've learned so we can all like collaborate together with. So that's great.' (LE) |

162

# Appendix J: Phase Four: Thematic Mapping



# Appendix K: Phase Five Analysis: Mapping themes

**Mapping Theme 1 in relation to central organising concept**

<table>
<tr><td colspan="3">Theme: Co-learners (Educators and children)</td></tr>
<tr><td colspan="3">Central organising concept:<br>The educators developed computational thinking by doing it with the children</td></tr>
<tr><td colspan="3">(Why) What are the underlying elements of this theme?</td></tr>
<tr><td>Before.<br>The educators beliefs about how they learn:<br>• learn by doing – figure things out-learn as they go<br>• learn how to use digital tech by watching or being shown by children<br>(Pre- interview)</td><td>Start of.<br>The educators felt overwhelmed with how to use the PRK<br>Felt they needed to figure it out for themselves – but couldn't do this without doing it with the children.<br><br>(Post -interview)</td><td>Motivating factor: reduce the children's frustration.<br>Noticing the children were finding play with prk challenging- CT is complex- observing frustration.<br>'I had to do the thinking myself when the children didn't get it'<br>(Post- interview; PM6)</td></tr>
<tr><td colspan="3">How did the educators develop their CT with the children?<br>-I had to do the thinking myself- when they didn't get it<br>-I had to think like the children<br>-I learned by watching them and seeing the things they come up with<br>(Post interview; PM6; DB8, DB10)<br><br>Structured observations from different play sessions (PS):<br>PS6-simplifying for a child<br>PS7-simplying code sequence for mTiny to draw a square<br>PS8-providing verbal prompts when children create story sequences for mTiny<br>PS9-supporting thinking to programme mTiny to draw a rectangle<br>PS10- providing verbal prompts when children create story sequences for mTiny<br>(+RJ3,RJ4,RJ5)</td></tr>
<tr><td colspan="3">Developed over time- 'it took time'<br>Week 1- overwhelmed- unsure (Post-int)<br>Week 2- Awareness of CT (PM2; RJ2; PS3)<br>Week 3- developing CT in order to support the children (PM3; RJ3; PS6)<br>Week 4- Doing it with the children (RJ4; DB8; PS7; PS8)<br>Week 5- Comfortable with CT foundations (PM5; RJ5; DB10; PS9; PS10)<br>Week 6- Confidence and competence with CT foundations (Post-int; RJ6)</td></tr>
<tr><td colspan="3">Outcomes for the educators<br>1. Developed CT foundations<br>2. Confidence and competence to build on it. We realised…'once we had the foundations we could add it'.<br>3. Now motivated by 'what the children get out of it' [their play with PRK].<br>(post interview; RJ6)</td></tr>
</table>

# Appendix L: DCU Ethics Approval

Ollscoil Chathair Bhaile Átha Cliath
Dublin City University

DCU

Anna Barr
Institute of Education

8th January 2024

**REC Reference:** **DCUREC/2023/228 (Expediated Review)**

**Proposal Title:** Supporting early childhood educators to design learning experiences to develop young children's computational thinking through purposeful play with programmable robotics kits: A design-based research intervention.

**Applicant(s):** Anna Barr, Professor Deirdre Butler and Dr Thérése Farrell

Dear Colleague(s),

Thank you for your application to DCU Research Ethics Committee (REC). Further to its review by the committee and resting on the assumption of information accuracy and completeness, DCU REC is pleased to issue ethical approval for this research project. Please include reference to this approval in all materials used to recruit research participants.

Researchers are responsible for ensuring that the research project to which this ethical approval refers is carried out as specifically described in the application form. Should modifications to the research project be required at a later stage, researchers must submit a research amendment application form to REC for approval, prior to the implementation of modifications.

Please note that it is the responsibility of the PI to ensure that any other DCU compliance requirements relevant to the research project, such as those related to data protection, insurance, health and safety, or legal issues, are fully met in advance of initiating the project.

As part of DCU REC's ongoing monitoring process, a research progress report may be required. DCU REC will request this report from the PI as appropriate.

DCU REC wishes you every success in your research.

Yours sincerely,

Dr. Melrona Kirrane

**Dr. Melrona Kirrane**
Chairperson
DCU Research Ethics Committee

DCU
Research & Innovation

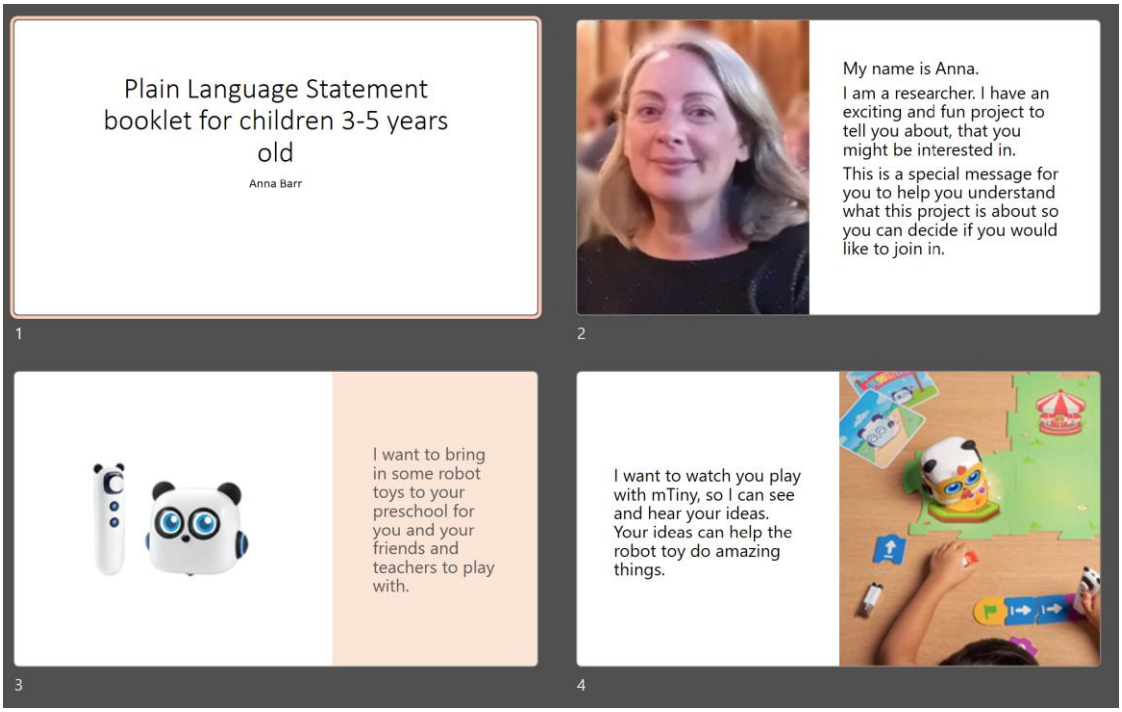
Taighde & Nuálaíocht Tacaíocht
Ollscoil Chathair Bhaile Átha Cliath,
Baile Átha Cliath, Éire

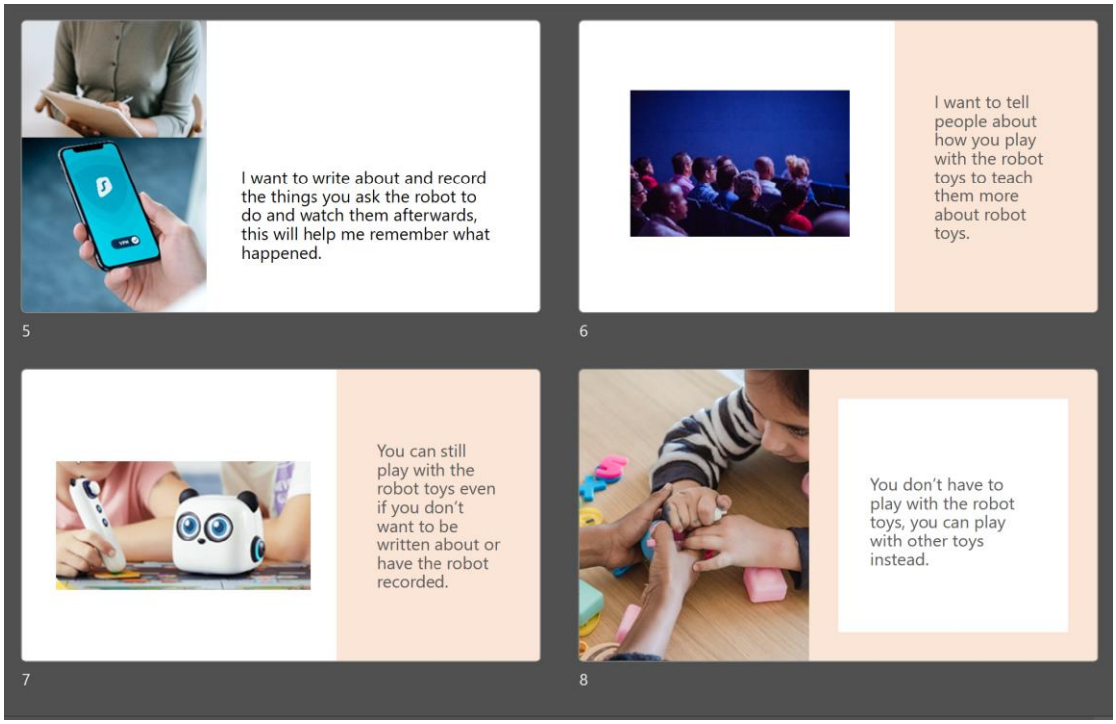
Research & Innovation Support
Dublin City University,
Dublin 9, Ireland

T +353 1 700 8000
F +353 1 700 8002
E research@dcu.ie
www.dcu.ie

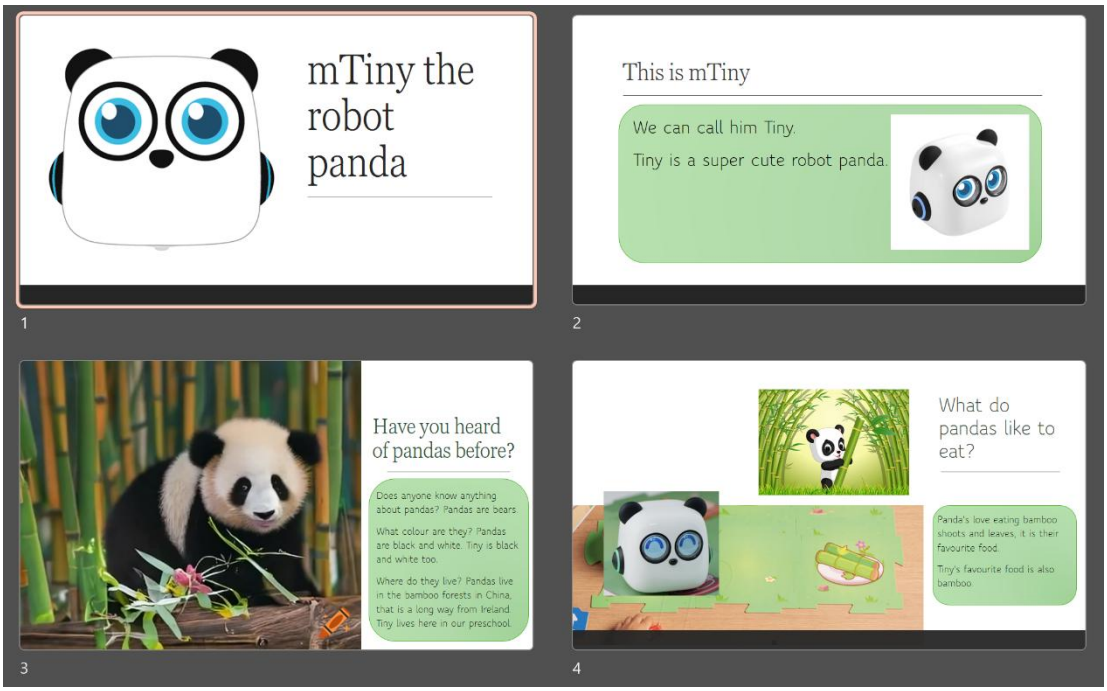
*Note: Please retain this approval letter for future publication purposes. Research students should include this letter as a thesis appendix.*

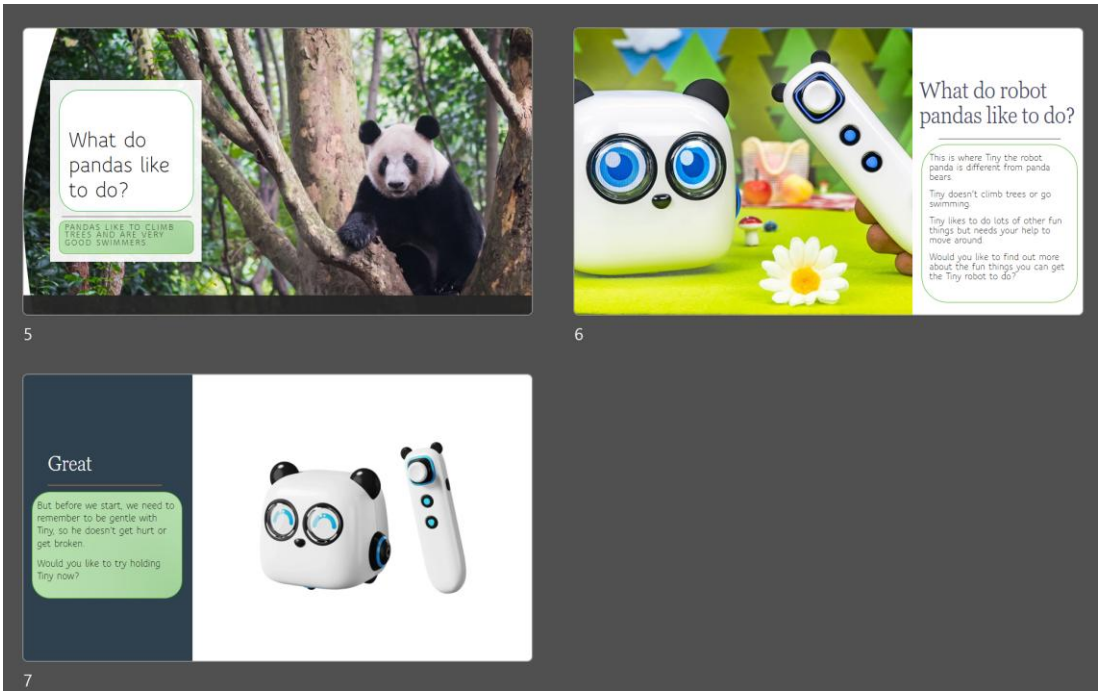
# Appendix M: Assent Booklet For Children



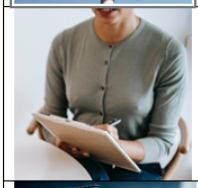
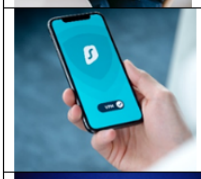
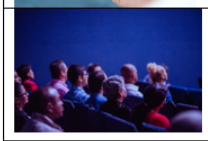



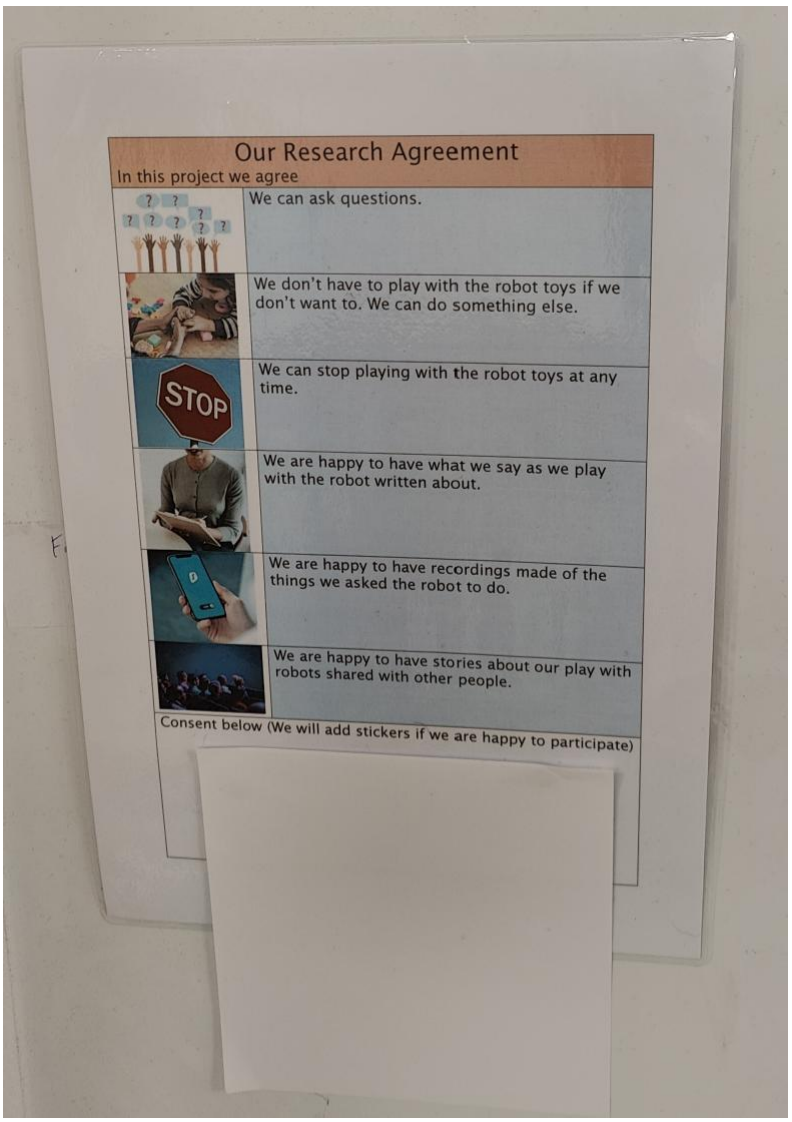
# Appendix N: Introduction to mTiny the robot panda booklet



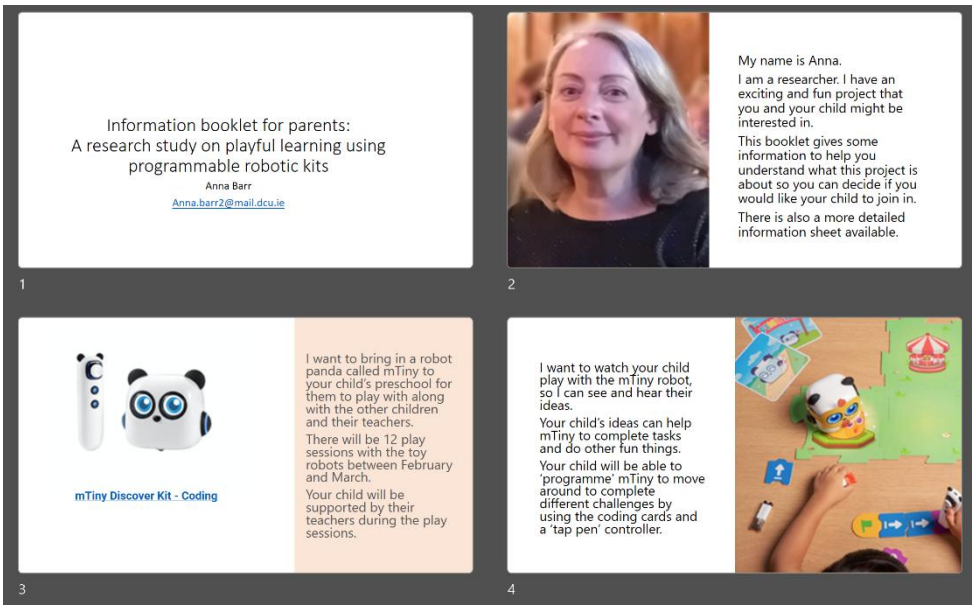
# Appendix O: Assent Chart Children with samples of Children's Assent

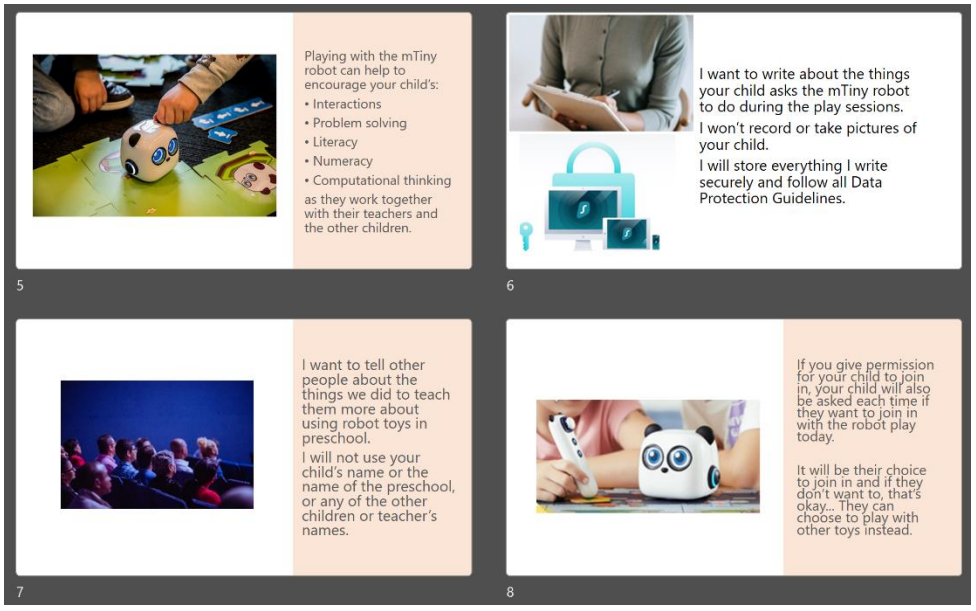
| Our Research Agreement<br>In this project we agree | |
|---|---|
|  | We can ask questions. |
|  | We don't have to play with the robot toys if we don't want to. We can do something else. |
|  | We can stop playing with the robot toys at any time. |
|  | We are happy to have what we say as we play with the robot written about. |
|  | We are happy to have recordings made of the things we asked the robot to do. |
|  | We are happy to have stories about our play with robots shared with other people. |
| Consent below (We will add stickers if we are happy to participate) | |


Our Research Agreement
In this project we agree
We can ask questions.
We don't have to play with the robot toys if we don't want to. We can do something else.
STOP
We can stop playing with the robot toys at any time.
We are happy to have what we say as we play with the robot written about.
We are happy to have recordings made of the things we asked the robot to do.
We are happy to have stories about our play with robots shared with other people.
Consent below (We will add stickers if we are happy to participate)


22nd Feb

# Appendix P: Information/ Informed Consent for Parents/Guardians



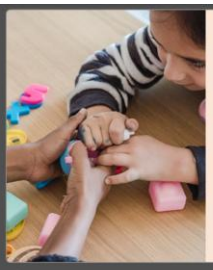
Your child can tell me or their teachers if they want to stop or take a break at any time.

If they do not feel comfortable taking part, they can stop immediately.

Your child won't have to take part after that.




9



If you decide that you do not want your child to join in with the robot play, that's okay.

Your child will be supported to choose to play with some other toys instead.

10

Does this sound okay?

Please let me know if you have any questions. You can send questions to your child's teacher or email me at: anna.barr2@mail.dcu.ie

If you are happy for your child to participate, please sign the consent form and let your child's teacher know.

Many thanks
Anna Barr



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## Participant information sheet- for Parents/ Guardians)

**Introductory Statement**
My name is Anna Barr, and I am currently conducting research as part of my doctoral studies in education at DCU, Institute of Education. The title of this research study is: *Supporting early childhood educators to design learning experiences to develop young children's computational thinking through purposeful play with programmable robotics kits: A design-based research intervention.* The research will be conducted under the supervision of Professor Deirdre Butler (School of STEM Education, Innovation & Global Studies, DCU) and Dr Thérèse Farrell (School of Language, Literacy & Early Childhood Education, DCU).

**What is this research about?**
This research study will focus on supporting early childhood educators to design playful learning experiences for the young children they work with. These playful learning experiences involve the use of programmable robotic kits with the aim of developing young children's computational thinking.

**Why is this research being conducted?**
This research is necessary to better understand how to support early childhood educators to use digital technologies, such as programmable robotic kits, as part of purposeful playful learning that aligns with a play-based approach to early childhood education in Ireland.
The research is also being conducted to better understand how to develop young children computational thinking through purposeful play with programmable robotic kits within an Irish early childhood setting. For this research study the children will have the chance to play with a small robot panda called mTiny. The children will be able to touch and hold mTiny and, 'programme' it to move around to complete different challenges by using the coding cards and a 'tap pen' controller. The way the children think about what they are doing and problem solve when they program mTiny can help to encourage their computational thinking.



**Why has your child been invited to take part?**
Your child is being invited to take part as they are 3-5 years old and currently attend the preschool setting that has agreed to take part in this research study.

**What will happen if you decide for your child to take part in this research study?**
Taking part in this research study involves your child participating in play sessions using the programmable robotic kits while attending their regular preschool sessions. There will be a total of 12 play sessions taking place over 6 weeks between February and March 2024; each play session will be about an hour long. These play sessions will involve your child exploring how to code and programme the robotic kits as they try to solve problems related to stories or scenarios. Your child will be supported by the early childhood educators and the researcher throughout the process. Even if you give permission for your child to take part, they may decide they don't want to participate during some or all of the play sessions, it will be their choice. Your child will have the freedom to choose from guided and free play opportunities that they are familiar with and currently enjoy.

**How will your child's data be used?**
Your child's participation in this research study will generate data that will contribute to the findings which will appear in a thesis, that may be published. The findings will also be used to inform articles that may be published in academic journals or ECEC publications, and may also be used as part of conference presentations, lectures and other relevant areas.

As part of this research study any personal data collected from your child will be processed in accordance with DCU's Data Protection Guidelines.

- The personal data will be collected and processed for research purposes only.
- The types of personal data to be processed: Informed Consent Forms (for parents); Informed Assent Forms (for children), Checklist Observations.
- Personal data will be used, at a later date, in pseudonymised form, with all potential identifiers removed for publishing the research results
- The pseudonymised data will be retained for a maximum period of five years after the research has been completed.
- The Data Controller is Dublin City University.
- The DCU Data Protection Officer is Mr. Martin Ward (data.protection@dcu.ie /Ph: 7005118 or 7008257) who will handle any data protection concerns arising from the research.
- Parents of child participants have the right of the individual to lodge a complaint concerning the use of personal data with the Irish Data Protection Commission.
- Parents of child participants have the right to access their child's personal data and can contact (someone on the research team) or the Data Protection Unit.

**How will your child's privacy be protected (including any legal limits to confidentiality)?**
Every effort will be made to protect the confidentiality of your child. Your child's information and the early childhood setting information will be anonymised or pseudo-anonymised, and data will remain confidential. While every effort will be made to protect the confidentiality of your child throughout the study, please note that confidentiality of information can only be protected within the limitations of the law - i.e., it is possible for data to be subject to subpoena, freedom of information claim or mandated reporting by some professions.

**What are the benefits of my child taking part in this research study?**
Participating in the play sessions with the programable robotic kits is intended to support your child's development of computational thinking skills, that include logical thinking and algorithmic thinking. These new ways of thinking can indirectly support their literacy and numeracy and help them develop positive learning dispositions such as problem solving, creativity, preserving and collaborating as they work together to create the code and programme the robots. Programming the robots also supports their digital literacy, which is now recognised as an essential skill alongside literacy and numeracy, and will be further developed in primary school.

**What are the risks of my child taking part in this study?**
There are no anticipated risks to taking part in this research study, however if your child becomes uncomfortable during the play sessions, they can choose not to participate and can instead choose to play with something else. If at any time there is an indication that your child's safety or well-being is being negatively affected, the research will be suspended until the issue has been addressed and you will be informed and offered appropriate support. If you notice any adverse effects from your child participating in the study, you can contact the researcher or the DCU Research Ethics Committee through the details provided below.

**Can you change your mind at any stage and withdraw your child from this study?**
Participation is voluntary. If you decide not to give permission for your child to take part, they will be supported to participate in guided and free play opportunities that they are familiar with and currently enjoy as part of the current curriculum and daily routine. You are free to withdraw your child from the study at any stage during the process by emailing anna.barr2@mail.dcu.ie, without giving a reason. If you wish to withdraw consent at any stage, any data relating to you and your child can be removed at any time up to the point of publication.

**How will you find out what happens with this project?**
A summary report on the findings will be sent to the early childhood setting and will be shared with participants and parents of child participants.

**Contact details for further information:**
Further queries on this research project can be addressed to the principal researcher Anna Barr by emailing anna.barr2@mail.dcu.ie. Queries or issues can also be addressed to Professor Deirdre Butler (@dcu.ie) or Dr Thérèse Farrell (@dcu.ie).

If participants have concerns about this study and wish to contact an independent person, please contact: The Secretary, Dublin City University Research Ethics Committee, c/o Research and Innovation Support, Dublin City University, Dublin 9. Tel 01-7008000, e-mail rec@dcu.ie

## Consent Form -Parents/Guardians of children Participants

**Research Study Title:**
Supporting early childhood educators to design learning experiences to develop young children's computational thinking through purposeful play with programmable robotics kits: A design-based research intervention.

The research will be conducted under the supervision of Professor Deirdre Butler (School of STEM Education, Innovation & Global Studies, DCU) and Dr Thérèse Farrell (School of Language, Literacy & Early Childhood Education, DCU).

Your child is invited to participate in this research study focusing on supporting early childhood educators to design playful learning experiences using programmable robotic kits with the aim of developing young children's computational thinking.

Before signing please complete the following (Circle Yes or No for each statement)

| | |
|---|---|
| I have read the Plain Language Statement (or had it read to me) | **Yes/ No** |
| I understand the information provided | **Yes/ No** |
| I understand the information in relation to data protection | **Yes/ No** |
| I have had an opportunity to ask questions and discuss this study | **Yes/ No** |
| I have received satisfactory answers to all my questions | **Yes/ No** |
| I agree to my child participating in the play sessions with programmable robotic kits | **Yes/ No** |
| I agree to checklist observations being used to document my child's play and engagement with the programmable robotic kits | **Yes/ No** |
| I am aware that my child's personal data will be pseudo-anonymised prior to the publication of the final thesis | **Yes/ No** |
| I give permission for the researcher to retain pseudo-anonymized data collected as part of this research for use in future publications or presentations | **Yes/ No** |
| I understand that Dublin City University is the data controller | **Yes/ No** |
| I understand that I may withdraw my child from the research study at any point | **Yes/ No** |

**Signature:**

I have read and understood the information in this form. My questions and concerns have been answered by the researcher, and I have a copy of this consent form. Therefore, I consent for my child, (insert name here)_____ to take part in this research project.

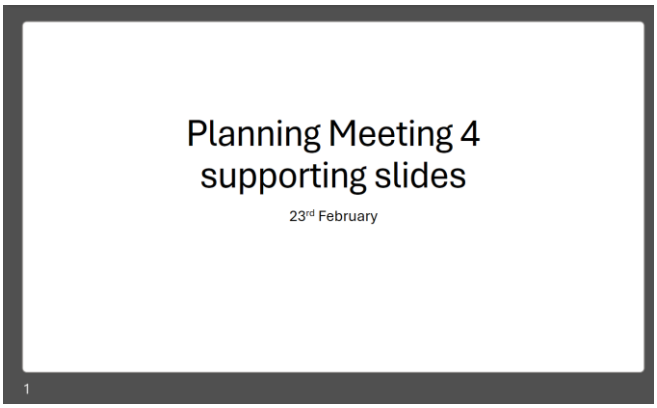
**Parent/ Guardian Signature:** _____

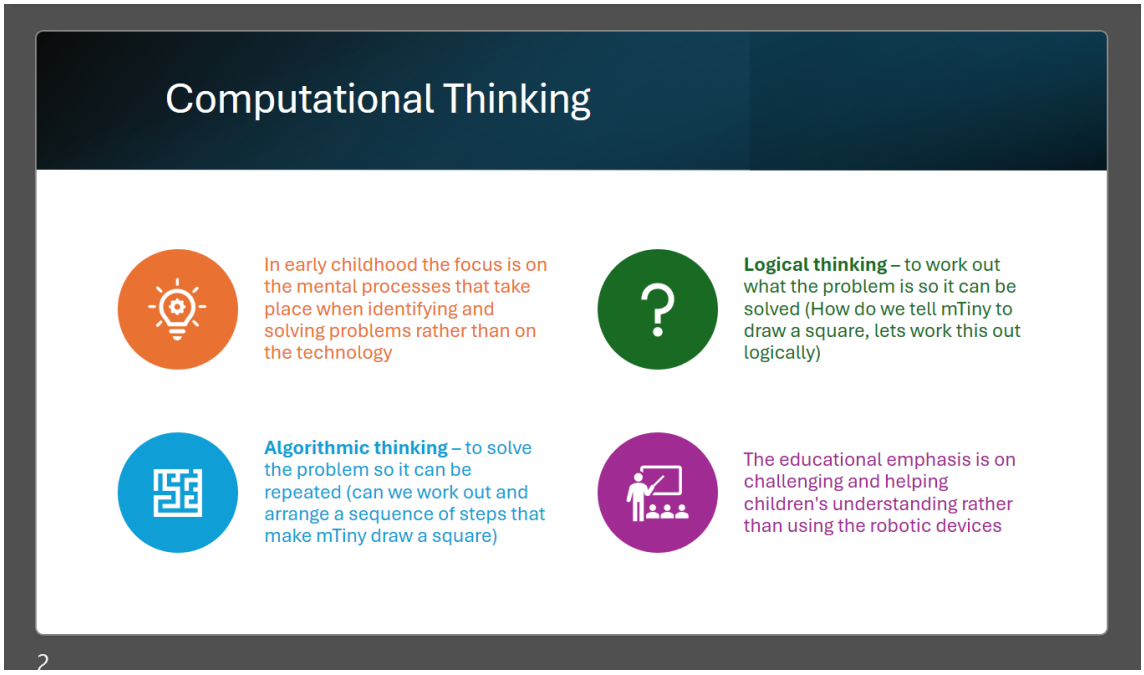
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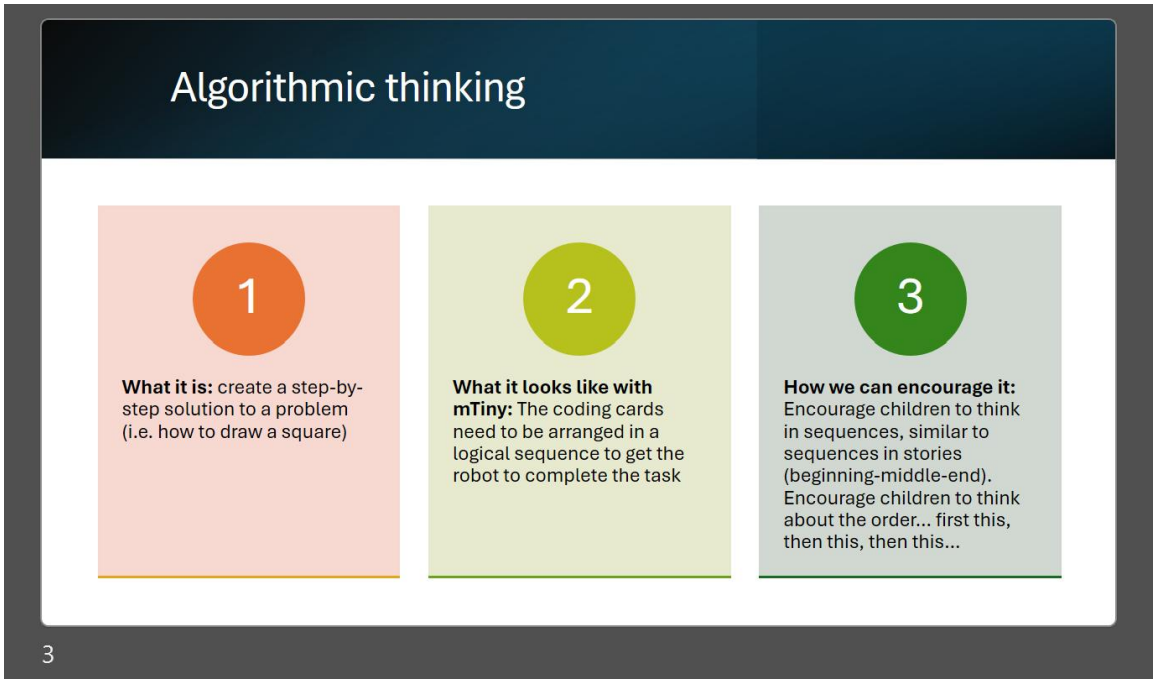
**Witness:**_____

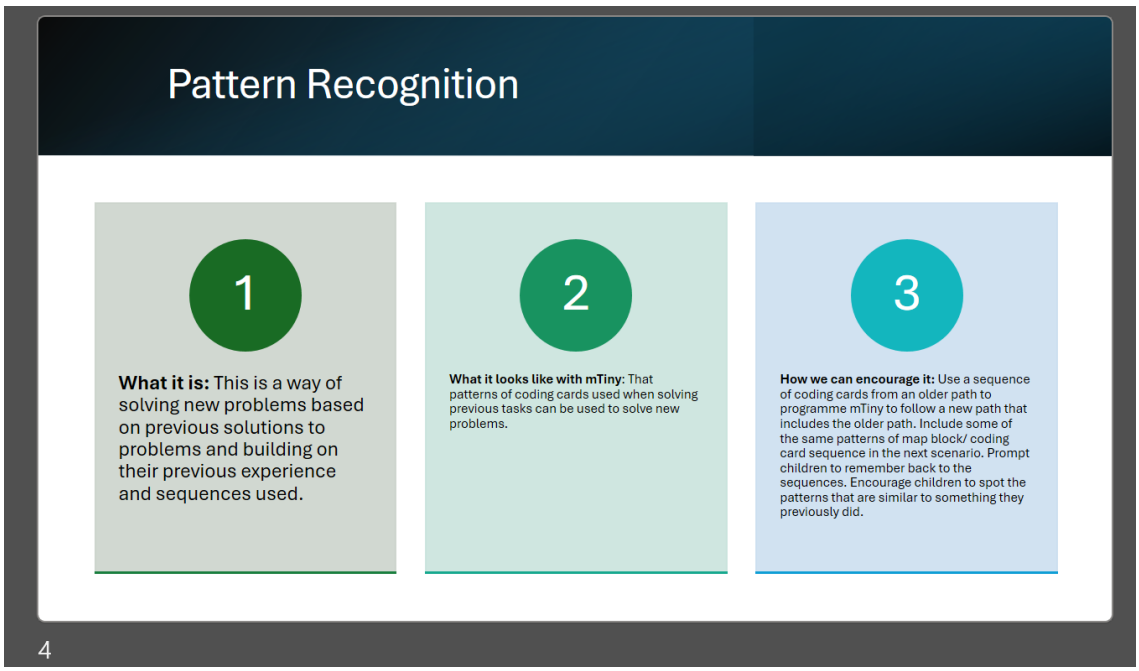
**Date:**_____

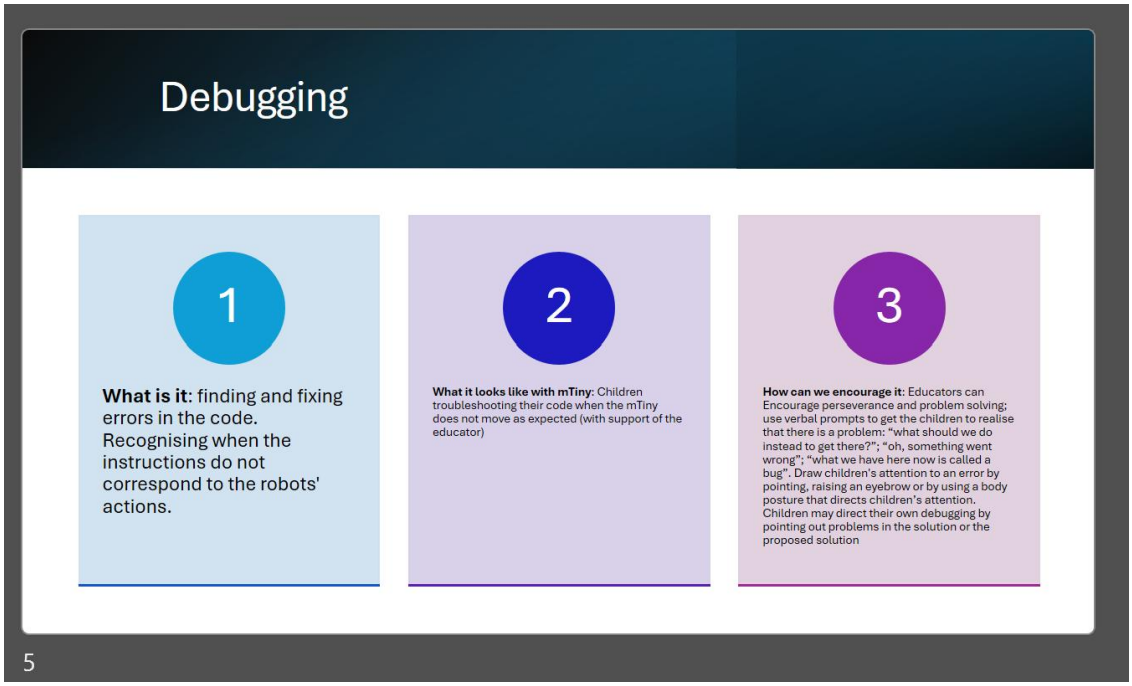
# Appendix Q: Planning Meeting 4 -slides




Pattern Recognition
1
What it is: This is a way of solving new problems based on previous solutions to problems and building on their previous experience and sequences used.
2
What it looks like with mTiny: That patterns of coding cards used when solving previous tasks can be used to solve new problems.
3
How we can encourage it: Use a sequence of coding cards from an older path to programme mTiny to follow a new path that includes the older path. Include some of the same patterns of map block/ coding card sequence in the next scenario. Prompt children to remember back to the sequences. Encourage children to spot the patterns that are similar to something they previously did.
4


Debugging
1
What it is: finding and fixing errors in the code. Recognising when the instructions do not correspond to the robots' actions.
2
What it looks like with mTiny: Children troubleshooting their code when the mTiny does not move as expected (with support of the educator)
3
How can we encourage it: Educators can Encourage perseverance and problem solving; use verbal prompts to get the children to realise that there is a problem: "what should we do instead to get there?"; "oh, something went wrong"; "what we have here now is called a bug". Draw children's attention to an error by pointing, raising an eyebrow or by using a body posture that directs children's attention. Children may direct their own debugging by pointing out problems in the solution or the proposed solution
5

# Appendix R: Plan for Play-Session 7

## Play Session 7 (PS7) Tuesday 27th Feb 2024

**Welcome and assent: Large group circle**
Researcher guides the children through the assent chart.
Children who are happy to participate attach a sticker to the assent chart (children not happy to participate can choose to play with something else). (**Aistear**: Principle 1: Agentic Global Citizens; Wellbeing Aim 4)

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**Learning Experience: Programming mTiny to draw a square**
**Learning goals**
With guidance from the educators the children will:

- Recognise there's a connection between the instructions they give mTiny and the action it performs (drawing a square) (CT: **Pattern Recognition)** (Aistear Exploring and Thinking, Aim 1,2).
- Identify a sequence of actions (move forward and move left) needed for mTiny to draw a square (CT: **Algorithms)** (Aistear Exploring and Thinking, Aim 2).
- Identify errors in the sequence of actions and with support make changes and try again (CT: **Debugging**) (Aistear Wellbeing Aim 4; Communicating Aim 2; Exploring and Thinking, Aim 4).

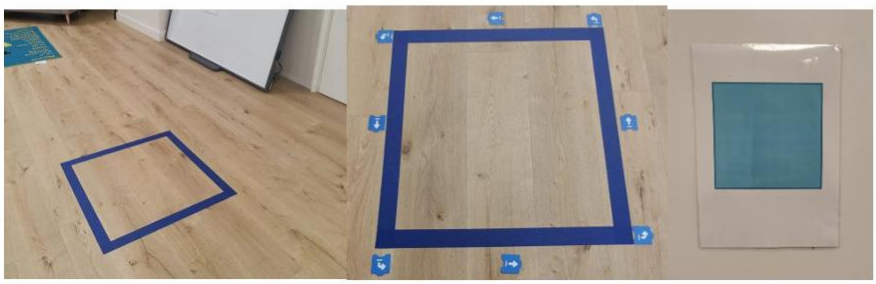
**Scenario**: Did you know mTiny can draw shapes. Relate this to the learning the children have been doing in recent weeks about shapes.

**Challenge**:
Programme mTiny to draw a square using move forward and move left and debug when things don't go according to plan

**Large group:** Unplugged activities (we won't use mTiny).
As a group let's think about what we know about squares and make connections to previous understanding on the directions 'move forward' and 'move left'.

- Name the shape (have a visual)
- Trace it with your finger (trace your finger in the air/ the square visual)
- Walk it (walk a square shape on the floor, naming the directions forward, turn (left)).
- Match the move forward and move left coding cards to the square shape (to a drawing, or the visual or floor shape)

The educational emphasis here is on supporting children to understand rather than using mTiny



**Small group**:
invite children to work out how to tell mTiny to draw a square.
Scaffold children to:

- Create a sequence of move forward and move left coding cards
- Add the input card and go card to run the programme

Did mTiny draw a square?... Do we need to debug the code?

- try to work out what went wrong, make some changes and try again

**Debugging** - when mTiny doesn't move the way we thought he would, we need to debug, work out what went wrong and how we can fix it. One way to do this is to call out the steps and see if we can find which part is wrong.

**Simplify**: instead of a very long code sequence (4x move forward and move left) we can simplify the code sequence to 1x move forward and move left and encourage the children to tap go four separate times to get mTiny to complete a square.
**More challenge**: Encourage children to think about the difference between a square and a rectangle... what could we add/ change to tell mTiny to draw a rectangle




**Individual / small group further exploration of shapes**
Invite children to explore:

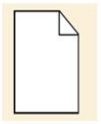
- Draw it (free hand drawing or using the Square Montessori inset shape, naming the forwards and turns)
- Arranging different codes sequences to see what shapes or patterns mTiny draws



**Resources:**










**Computational Thinking (CT) concepts:**
**Algorithmic Thinking** (children participate in arranging the coding cards in a logical sequence to get mTiny to move where they want)
**Pattern recognition** (children build on their previous learning and spot patterns when arranging the coding cards and when solving problems).
**Debugging** (children recognise that sometimes mTiny doesn't move the way they expected and when this happens they can participate in trying to work out what went wrong so they can think of ways to fix the problem.)

# Appendix S: Plan for Play-Session 8

## Play Session 8 (PS8): Co-create stories for mTiny

**Thursday 29th Feb 2024** This is a 30 minute play session

**Welcome and assent**

Researcher guides the children through the assent chart.

Children who are happy to participate attach a sticker to the assent chart (children not happy to participate can choose to play with something else).

(**Aistear**: Principle 1: Agentic Global Citizens; Wellbeing Aim 4)

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**Learning goals**

With guidance from the educators the children will:

- Create as story for mTiny
- Identify sequence of actions needed for mTiny to move as part of their story (CT: **Algorithms; Pattern recognition)**
- Identify errors in the sequence of actions and with support make changes and try again (CT: **Debugging**)

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**Scenario**: Invite the children to share their plans for mTiny: the map block design, what mTiny will do, where mTiny will go. Support children to plan a sequence; a beginning-middle-end to their story or scenario.

**Challenge**: The children create the challenge for mTiny. Educators support the children to build on previous understanding and recognise pattern from previous play sessions (move forward, move left, input and sequence cards, emotions cards)

**Simplify**: select a scenario from the booklet.

**More challenge**: create bigger map block arrangements and have more parts to the story.

**Large group:**
Share visuals of map block arrangements and mTiny scenarios from the mTiny booklet for visual inspiration. Give each child an opportunity to share their story and plans for mTiny.
**Small group**:

Encourage children to co-create their stories and scenarios together. Invite the children to select map blocks from the blue box and create their arrangements/ sequences of food/ events/ city places and to talk about their ideas.
Support the children to decide on the sequence *first this-then this-then this* (break into smaller steps). Starting with the first place they want mTiny to go, guide them to tap or arrange the coding cards in a logical sequence
**Resources:**

Map blocks, move forward, move left, input, go cards, emotions cards.

Computational Thinking (CT) concepts:

**Algorithms** (children participate in arranging the coding cards in a logical sequence to get mTiny to move where they want)

**Pattern recognition** (children build on their previous learning and spot patterns when arranging the coding cards and when solving problems).

**Debugging (children recognise that sometimes mTiny doesn't move the way they expected and when this happens they can participate in trying to work out what went wrong so they can think of ways to fix the problem.)**

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Relevant Aistear Themes and Aims:

Wellbeing

Aim 4: Young children will be agentic global citizens and have positive outlooks on learning and on life.

- Develop holistically and show a sense of mastery and belief in their own abilities, take learning risks, and **display learning dispositions such as determination, perseverance, independence, resilience, empathy and resourcefulness**.

Communicating:

Aim 2: Young children will use language(s)

- **Interact with others** for giving and receiving information, listening and taking turns in conversations and **storytelling, clarifying thinking, ideas and feelings, asking questions, refusing, negotiating, and problem-solving**.

Exploring and Thinking:

Aim 1: Young children will learn about and make sense of the world around them.

- **Have opportunities to explore their world through** integrated artistic, linguistic, geographical, historical, scientific, **technological**, engineering **and mathematical learning experiences through play.**

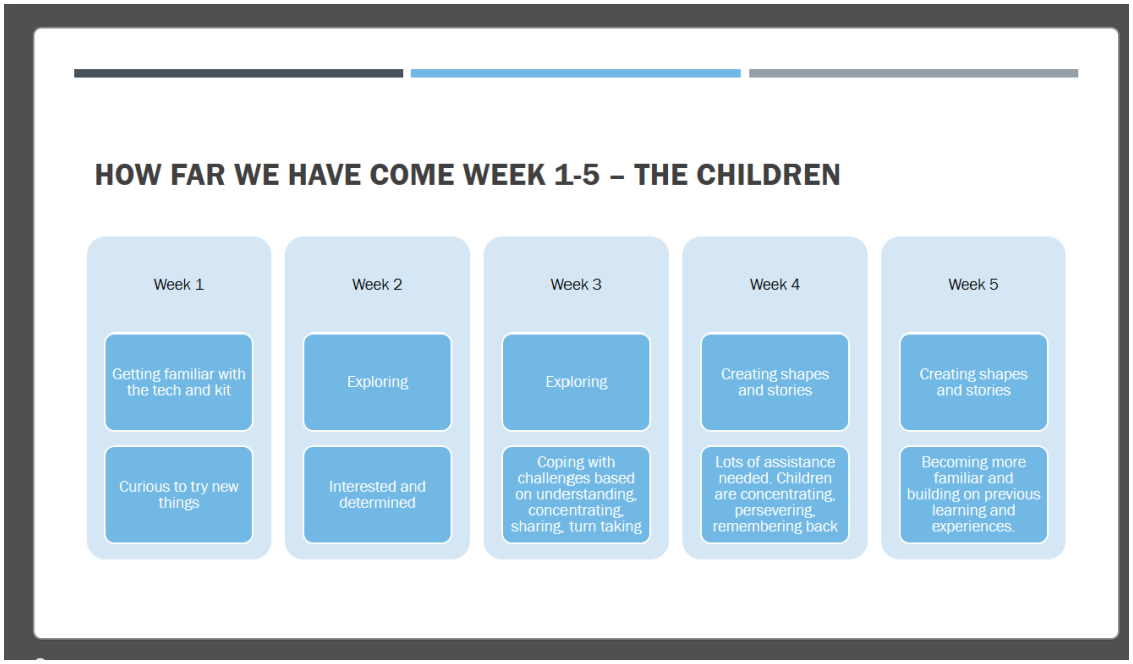
Aim 2: Young children will develop and use skills and strategies for observing, questioning, investigating, understanding, negotiating and problem-solving and come to see themselves as explorers and thinkers.

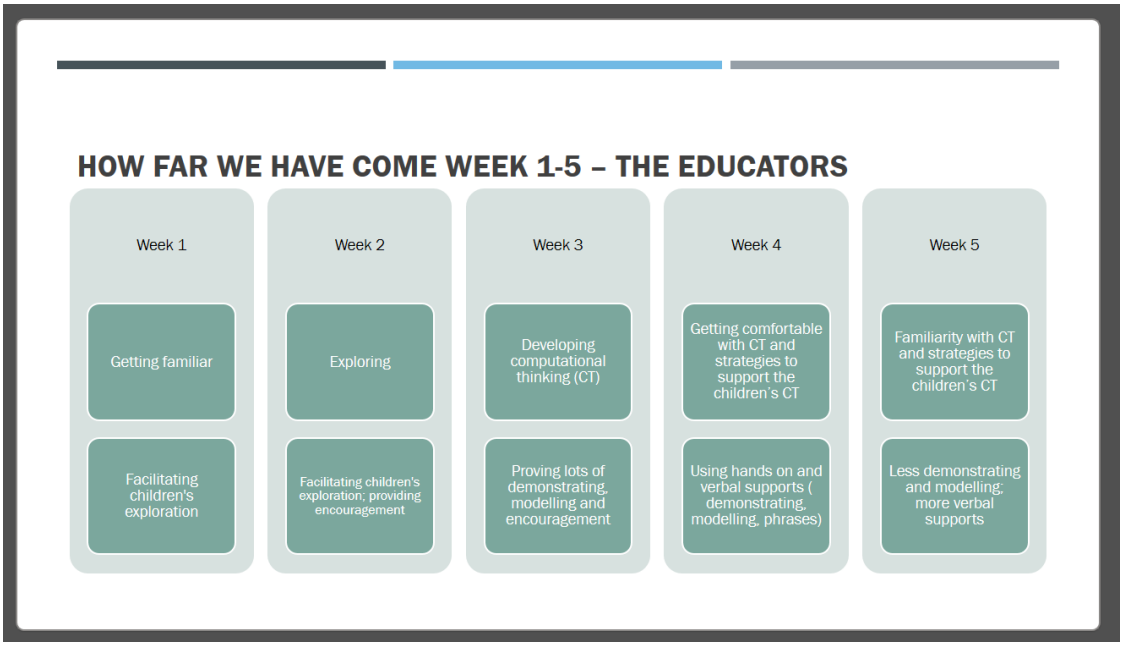
- **Make connections and associations between new learning and what they already know**, having the time and space to explore and develop theories about how the world works.
- **Collaborate and play with others** to share interests, to learn about the past, the present and the future, **to solve problems, be creative and think logically.**

Aim 4: Babies, toddlers and young children will have positive attitudes towards learning and develop dispositions like independence, curiosity, playfulness, perseverance, resilience, confidence, resourcefulness and risk-taking.

# Appendix T: Outline of Children and Educators Progress Weeks 1-5



# Appendix U: Participation in Play-Sessions 1-12

Children participants attendance and engagement with CT concepts – based on structured observations rating scale - Appendix

| Child | Number of Play Sessions (PS) attended | PS1 | PS2 | PS3 | PS4 | PS5 | PS6 | PS7 | PS8 | PS9 | PS10 | PS11 | PS12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CP1 | 7 | - | - | - | - | √ | √ | √ | √ | - | √ | √ | √ |
| CP2 | 5 | - | - | - | - | √ | √ | √ | - | - | - | √ | √ |
| CP3 | 11 | √ | - | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ |
| CP4 | 6 | √ | √ | - | - | √ | - | √ | - | √ | - | √ | - |
| CP5 | 12 | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ |
| CP6 | 12 | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ |
| CP7 | 2 | √ | √ | - | - | - | - | - | - | - | - | - | - |
| CP8 | 11 | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | - |
| CP9 | 8 | √ | √ | - | - | - | - | √ | √ | √ | √ | √ | √ |
| CP10 | 11 | - | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ |
| CP11 | 7 | √ | √ | √ | √ | - | √ | √ | √ | - | - | - | - |

**Average levels of engagement with CT concepts during the play sessions (PS)**
**Rating Scale: 0** -did not attempt; **1**-Did not achieve; **2** Achieves with significant assistance; **3-** Achieves with some assistance; **4-** Achieves with minimal assistance; **5**-Achieves without assistance

| Play session | PS1 | PS2 | PS3 | PS4 | PS5 | PS6 | PS7 | PS8 | PS9 | PS10 | PS11 | PS12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Play session activity | Explore moving mTiny with the joypad | Tap move forward x 4 | Aligning move forward with map blocks and creating a programme | Move forward programme sequence | Adding in move left and right (city road map) | Sequences of move forward and move left | Programme mTiny to draw a square | Developing own story and map sequence for mTiny | Programme mTiny to draw a rectangle | Developing own story and map sequence for mTiny | Developing own story and programme sequence for mTiny | Developing own story and programme sequence for mTiny |
| CP1 | - | - | - | - | 0 | 0 | 3 | 3-4 | - | 4 | 4 | 4 |
| CP2 | - | - | - | - | 2 | 2 | 3 | - | - | - | 3 | 3 |
| CP3 | 4 | - | 3 | 3 | 2 | 2 | 2 | 3 | 3 | 3 | 4 | 4 |
| CP4 | 3 | 3 | - | - | 1 | - | 2 | - | 2 | - | 2 | - |
| CP5 | 3 | 4 | 3 | 3 | 3 | 2 | 3 | 3-4 | 3-4 | 4 | 4 | 4 |
| CP6 | 4 | 3 | 3 | 3 | 1 | | 2 | 2-3 | 2 | 3 | 3 | 3 |
| CP7 | 0 | 0 | - | - | - | - | - | - | - | - | - | - |
| CP8 | 3 | 3 | 3 | 0 | 2 | 2 | 2 | 0 | 2 | 3 | 3-4 | - |
| CP9 | 3 | 4 | - | - | - | - | 2 | 3 | 3 | 3 | 3 | 3 |
| CP10 | - | 3 | 2 | 1 | 1-2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| CP11 | 3 | 1 | 2 | 0 | - | 0 | 2 | 1-2 | - | - | - | - |

# Appendix V: Play-Sessions Structure

| **Play Session Structure** |
|---|
| This is a 30 minute play session that can be run two times over the hour (9:30-10am, and 10-10:30am). |
| **Welcome and assent (5 mins)** |
| Whole group circle:<br>1 researcher-mentor; 2 educators; up to 11 children<br>• Researcher-mentor reads through the research information booklet and assent chart.<br>Children who are happy to participate attach a sticker to the assent chart (children not happy to participate can choose to play with something else) (**Aistear**: Principle 1: Agentic Global Citizens; Wellbeing Aim 4) |
| **Whole group (10 mins)** |
| Researcher-mentor introduces the scenario for mTiny and the purposeful play computational thinking challenge for the children.<br><br>The researcher-mentor:<br>• Demonstrates with mTiny, models the thinking and gives verbal prompts.<br>• Encourages the children to think back to what they already know or programming they tried last week<br>• Then invites children one by one to try for themselves.<br><br>The educators<br>• Encourage the children to watch each other and suggest or help each other.<br>• Observe the researcher-mentors strategies to support the children's learning and use this to build their understanding and strategies. |
| **Small group (10 mins)** |
| The researcher-mentor and educators:<br>• invite the children to form small groups of 2-3 on each mat<br>• invite small group to co-create their own version of scenario with the PRK.<br>• Scaffold the children to engage in the scenario and challenge introduced to the whole group by breaking up large or multi-steps into small tasks or adding more challenge to the scenario as needed.<br>• Foster exploring, tinkering and debugging through guided participation<br>• Guide participation through modelling actions and thinking, being a co-player,<br>• Encourage the children to explore, tinker and debug any mistakes or problems with the coding card sequence. |
| **Bring session to an end (5 mins)** |
| The researcher-mentor and educators:<br>Invite the children to finish what they are working on and prepare to tidy up and transition to the next part of their daily routine. |

## Key Learning intentions and strategies for the Play Sessions

**Children's learning approach**:

- Creating (map block arrangements, scenarios and solving challenges for mTiny)
- Exploring, tinkering and testing (how to get mTiny to complete the challenges)

**Educators pedagogical approaches**:

- Plan purposeful opportunities to explore, play and tinker with the mTiny
- Demonstrate and scaffold new ways of thinking and doing things
- Create stories and scenarios that build on children's strengths and interests
- Provide guided participation – encourage dialogue, thinking, problem solving, be a play partner, co-creator and co-learner

**Computational Thinking Concepts**

--**Abstraction** (The colours and symbols on the coding cards represent different types of actions and they will need to work out the best use of these cards; they can execute commands such as 'move forward')

-**Algorithms** (The coding cards need to be arranged in a **logical sequence** to get the robot to complete the task)

-**Pattern recognition** (They build on previous learning and spot patterns to solve the problems/ complete the task).

-**Iteration** (That they need to move through an **iterative process, repeating steps or the problem solving process)**

-**Debugging (Troubleshoot** their code when the mTiny does not move as expected)

-**Decomposition** Break up a larger event (with multiple steps) into individual task sequences that mTiny can complete one at a time )

**Links to the updated Aistear principles (NCCA, 2024):**

**Principle 1: Agentic Global Citizens**
Children will be encouraged to communicate their opinions, choices and needs throughout the play sessions and will make adjustments based on these.

**Principle 2: Diversity, Equity and inclusion**
Learning experiences will be planned to encourage active participation of all children; recognising the children's abilities (strengths and interests) and potential when planning the play sessions.

**Principle 3: Relationships and interactions**
The play sessions designs will support and encourage children's sharing of ideas, collaboration and problem solving.

**Principle 5: Agentic Educators**
Learning experiences will be planned to encourage active participation of all children; recognising the children's abilities (strengths and interests) and potential when planning the play sessions

**Principle 7: Holistic learning and development**
Researcher-mentor and educators will observe/ notice what the children do, say and make during the play sessions; the debrief sessions and planning meetings will then provide opportunity for us to review and reflect before making plans for the next week.

The play sessions design will build on children previous experiences, strengths, interests and needs. The play sessions will provide opportunities for children will develop as thinkers.

**Principle 8: Play and Hands-on Experiences**
The play sessions will be designed to supports them to develop as thinkers; through hands-on active learning that encourages the children to enquire (question and think), explore, be creative and use their imagination and offers challenge.

**Principle 9: Learning Environments**
The learning environment design will facilitate children to collaborate, make choices and offer appropriate challenge

**Links to the updated Aistear themes and aims (NCCA, 2024)**

| **Theme and Links to the Aims** |
| --- |
| **Wellbeing** |
| Wellbeing is being supported when the children…<br><br>Have **positive attitudes and make positive choices** when exploring with the mTiny robot and tap pen controller. **(Aim 2)**<br><br>Are encouraged to **communicate their thoughts, feelings and have a say** while exploring with mTiny and cope with challenges. **(Aim 1; 4)**<br><br>Are being agentic learners; when they **make choices and decisions** and express their preferences when exploring with mTiny. (Aim 4)<br><br>Have opportunities to **develop positive learning dispositions** such as problem solving, determination, perseverance, independence, resilience, empathy and resourcefulness, confidence, creativity curiosity, taking learning risks **(Aim 1; 3; 4)**<br><br>Can make connections between mTinys emotion cards and responses and their own feelings, emotions and life experiences. **(Aim 1)** |
| **Identity and Belonging** |
| Identity and Belonging is being supported when the children…<br><br>Feel valued and respected during the play session; that the **play sessions are meaningful and build on their experiences, interests, strengths** and their needs are supported (they are active participants). **(Aim 1; 2)**<br><br>Are **supported to collaborate with their peers and the educators** as they explore with mTiny; they are supported to negotiate, cooperate, engage in conflict resolution and respects others when making problem solving decisions **(Aim 2; 3)** |

Engage in the challenges as they explore with mTiny. Theres opportunities for them to **develop positive learning dispositions (behaviours skills, and attitudes)** such as confidence and self-assurance, self-regulation, sharing/collaborating, curiosity, persistence, independence and responsibility through engagement with playful learning experiences. **(Aim 3; 4)**

**Communicating**

Communicating is being supported when the children...

**Make connections between mTinys emotion cards and responses** and the vocalisations and facial expressions people use to express themselves. **(Aim 1)**

Are supported **to interact with their peers and educators to clarify thinking,** ideas and feelings, ask questions, negotiate, and problem-solve when exploring with mtiny; Educators will encourage children to give and receive information, to listen and take turns conversations. **(Aim 2; 4)**

**Make connections between the colours and symbols** on the action cards, emotions cards, input card and go card; that these represent different types of actions for mTiny to complete. **(Aim 3)** (CT concept (CT concepts: Abstraction)

Engage in the challenge as they explore with mTiny. Theres opportunities for them to **develop positive learning dispositions** (behaviours skills, and attitudes) such as confidence, creativity, taking learning risks, problem-solving and thinking critically, problem solving and collaborating. **(Aim 2, 3; 4)**

**Exploring and Thinking**

Exploring and thinking is being supported when the children...

Engage, explore and experiment in their environment through play with mTiny and with others. (**Aim 1**)

Demonstrate growing **confidence in being able to do things for themselves,** seeing themselves as agentic learners open to new ideas and experiences.(Aim 4)

**Develop computational thinking skills** such as logical thinking, sequencing, problem-solving, predicting, analysing, questioning and justifying **through their playful explorations with mTiny (Aim 2; 4)** (CT concepts: Abstraction; Algorithms ; Decomposition; Pattern Recognition; Debugging; Iteration)

Engage in the challenges are they explore with mTiny. Theres opportunities for them to **develop positive learning dispositions** (behaviours skills, and attitudes) such as confidence, problem-solving, perseverance, resilience, resourcefulness, taking learning risks, creativity, collaborating **(Aim 1; 2; 4)**

# Appendix W: Overview of Play-Sessions 1-12

| Week number | Play Session | Overview | Learning goals<br>With guidance from the educators the children will: |
|---|---|---|---|
| **Week 1** | **PS1** | Researcher introduce the children to one of the mTiny robots (Tiny) by telling the story of Tiny the robot panda.<br>**Explore with mTiny using the controller joypad function.**<br><br> | – Understand there is a relationship between the mTiny and the controller.<br>– Understand that they tell mTiny where to move by using the controller.<br>– Purposefully move mTiny using the controller<br>(Aistear Exploring and Thinking, Aim 1,2.) |
| | **PS22** | **Introduce the 'tap' pen function and the coding card 'move forward'**<br>Let's work out how many 'move forward' cards/steps mTiny needs to take to get to the bamboo.<br>Tap move forward x 4<br><br><br> | – Understand there is a relationship between mTiny and the map blocks<br>– Understand there is a relationship between the mTiny, the controller and the coding cards.<br>– Purposefully move mTiny tapping the controller on coding cards<br>– Understand that the colours and symbols on the coding cards represent different types of actions (CT concept: Abstraction)<br>(Aistear Exploring and Thinking, Aim 1,2,4) |
| **Week 2** | **PS3** | **Aligning move forward with map blocks and creating a programme.**<br>Let's work out how many 'move forward' cards/steps mTiny needs to take to get to the event/ food map block.<br> | – Understand there is a relationship between the mTiny, the controller and the coding cards and map blocks.<br>– Purposefully move mTiny by tapping the controller on coding cards<br>– Understand that the colour and symbol on the coding cards, input card and go card represent different types of actions- build on learning from previous play session 2. (CT concept: Abstraction; Pattern Recognition; Algorithms;)<br>– Understand and be able to arrange the coding cards in a logical sequence from starting point to the end point for the programme to successfully get mTiny to the complete the task<br>(Aistear Exploring and Thinking, Aim 1,2,4) |

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| | PS4 | **Programme mTiny using move forward**<br>Move forward programme sequences<br>**Add emotion cards to the programme**<br> | Learning goals are the same as play session 3.<br>The key learning goal is to build on learning from previous play session 3 |
| Week 3 | PS5 | **Programme mTiny using move forward, move left and debug when things don't go according to plan**<br>Adding in move left and move right direction cards (city road map)<br> | – Recognise that the blue move forward, move left and move right coding cards tell mTiny to move in different directions and will participate in arranging the blue direction coding cards in a sequence to try and get mTiny to move where they want. (CT: Algorithms; Pattern recognition)(Aistear Exploring and Thinking, Aim 2,4)<br>– participate in problem solving, try to work out what went wrong, when mTiny doesn't move the way they thought. (CT: **Debugging; Pattern recognition; Iteration)** (Aistear Exploring and Thinking, Aim 2,4; Communicating Aim 2) |
| | PS6 | **Programme mTiny using move forward, move left and debug when things don't go according to plan**<br>Sequences of move forward and move left | – Recognise that the blue move forward and move left coding cards tell mTiny to move in different directions and will participate in arranging the blue direction coding cards in a sequence to try and get mTiny to move where they want. (CT: **Algorithms; Pattern recognition)** (Aistear Exploring and Thinking, Aim 2,4)<br>– Participate in problem solving and persevere when mTiny doesn't move the way they thought by working together to try and understand what went wrong. (CT: **Debugging; Pattern recognition; Iteration)** (Aistear Exploring and Thinking, Aim 2,4; Communicating Aim 2) |
| Week 4 | PS7 | **Drawing squares with mTiny**<br>Programme mTiny to draw a square<br> | - Recognise there's a connection between the instructions they give mTiny and the action it performs (drawing a square) (CT: **Pattern Recognition)**<br>- Identify a sequence of actions (move forward and move left) needed for mTiny to draw a square (CT: **Algorithms)** (Aistear Exploring and Thinking, Aim 2).<br>- Identify errors in the sequence of actions and with support make changes and try again (CT: **Debugging**) (Aistear Wellbeing Aim 4; Communicating Aim 2; Exploring and Thinking, Aim 4). |
| | PS8 | **Co-create stories for mTiny**<br>Developing own story and map sequence for mTiny | – Recognise there's a connection between the instructions they give mTiny and the action it performs (Aistear Communicating Aim 2; Exploring and Thinking, Aim 1,2).<br>- Identify sequence of actions needed for mTiny to move as part of their story (CT: **Algorithms; Pattern recognition)** (Aistear Communicating Aim 2; Exploring and Thinking, Aim 2).<br>- Identify errors in the sequence of actions and with support make changes and try again (CT: **Debugging**) (Aistear Wellbeing Aim 4; Communicating Aim 2; Exploring and Thinking, Aim 4). |

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| Week 4 | PS9 | **Drawing rectangles with mTiny**<br>Programme mTiny to draw a rectangle | - Build on previous understanding from PS7, drawing a square, when thinking about how mTiny can draw a rectangle (CT: **Pattern Recognition)** (Aistear Exploring and Thinking, Aim 1,2).<br>- Identify a sequence of actions (move forward and move left) needed for mTiny to draw a rectangle (CT: **Algorithms)** (Aistear Exploring and Thinking, Aim 2).<br>- Identify errors in the sequence of actions and with support make changes and try again (CT: **Debugging**) (Aistear Wellbeing Aim 4; Communicating Aim 2; Exploring and Thinking, Aim 4). |
| | PS10 | **Co-create stories for mTiny**<br>Developing own story and map sequence for mTiny | - Build on previous understanding from PS8<br>- Recognise there's a connection between the instructions they give mTiny and the action it performs (Aistear Communicating Aim 2; Exploring and Thinking, Aim 1,2).<br>- Identify sequence of actions needed for mTiny to move as part of their story (CT: **Algorithms; Pattern recognition)** (Aistear Communicating Aim 2; Exploring and Thinking, Aim 2).<br>- Identify errors in the sequence of actions and with support make changes and try again (CT: **Debugging**) (Aistear Wellbeing Aim 4; Communicating Aim 2; Exploring and Thinking, Aim 4). |
| Week 6 | PS11 | **Co-create stories for mTiny / extend play with mTiny based on curriculum interests transport and block play**<br>Developing own story and programme sequence for mTiny | - Build on previous understanding from PS8,10<br>- Identify sequences of actions needed for mTiny to move as part of their story (CT: **Algorithms; Pattern recognition)** (Aistear Exploring and Thinking, Aim 1,2).<br>- Identify errors in the sequence of actions and with support make changes and try again (CT: **Debugging**) (Aistear Communicating Aim 2; Exploring and Thinking, Aim 2). |
| | PS12 | **Co-create stories for mTiny / extend play with mTiny based on curriculum interests transport and block play.**<br>Developing own story and programme sequence for mTiny | - Build on previous understanding from PS8,10,11<br>- Identify sequences of actions needed for mTiny to move as part of their story (CT: **Algorithms; Pattern recognition)** (Aistear Exploring and Thinking, Aim 1,2).<br>- Identify errors in the sequence of actions and with support make changes and try again (CT: **Debugging**) (Aistear Communicating Aim 2; Exploring and Thinking, Aim 2). |

Appendix X: Insights from Play-Sessions 1-12 that informed subsequent sessions

| Week DBR cycle | Play Session | Insight | How informed subsequent session |
|---|---|---|---|
| Week 1 | 1 | Good concentration during the whole group introduction to mTiny. however the **children started to lose focus** during small group exploration. With hindsight we should have regrouped the children to set up a new challenge for them.<br><br>**Taking turns and sharing was challenging** for the children. They need more support with this. | Play Session 2<br>We decided to:<br>– Divide the hour into smaller parts, moving from whole group to small group, then back to whole group to add a new layer of thinking/ challenge and finally small group.<br>– Focus on encouraging children to engage in cooperative and collaborative play with mTiny. |
| | 2 | Some children **lost interest or found it hard to focus** after the first 30 mins.<br>The **educators were more confident** with their small groups- talking through with children and guiding exploration and play.<br>What we planned was **appropriate for some of the children's capabilities and interests.** CT concepts observed- foundational level algorithmic thinking, pattern recognition. | Play-Session 3<br>We decided to:<br>– Divide the hour into 2x 30mins with smaller groups and rotate them.<br>– Revisit and build on the scenario and challenge from play-session 2. |
| Week 2 | 3 | The educators notice that **children play with the mTiny in different ways,** for example:<br>-Designing and building large sequences of map blocks as a story/ city for mTiny<br>-Viewing the map blocks as jigsaws to build first, then think about where mTiny will go<br>-Playing more freely with mTiny and the map blocks and coding cards. | Play Session4<br>We decided to:<br>– Build on their play interests<br>– Integrate the CT focus with children ideas of map block sequences and stories for mTiny. |
| | 4 | **Excellent engagement** in the programming as part of whole group scaffolding/ modelling. Counting, programming and trying to work out how to get mTiny to stop on the bone (map block).<br>However once they moved to small groups they found it very **challenging to get mTiny to turn** the way they wanted. This may be because they are creating complex map block sequences for mTiny. | Play-Session 5<br>We decided to:<br>– Find a balance between their ideas for the map block designs/ scenarios and having simpler sequences that build on their current understanding and computational thinking skills. |

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| **Week 3** | **5** | Similar to Play-session 4, once they moved to small groups they found it very **challenging to get mTiny to turn** the way they wanted. This was because they are creating complex map block sequences for mTiny. We notice that **when it is too challenging the children walk away**. | Play-session 6<br>I re-read my Literature review research articles on play with PRK and development of CT for children 3-6 years old to understand how we might reduce the challenge and foster perseverance.<br>Based on this, we decided to:<br>– Keep the focus on programming mTiny to turn<br>– Simplify the scenario and challenge<br>– Step in to model the thinking |
| | **6** | The educators **stepping in strategies were effective** in supporting the children to **make sense of which direction mTiny** will turn in based on which coding card is tapped.<br>The children were **more engaged** than last time.<br>The educators are developing their CT through these experiences supporting the children. | Play-session 7<br>We decided to:<br>– Build on understanding gained in Play-session 6<br>– Focus on programming mTiny to draw a square so as to build on understanding gained on mTiny turning. |
| **Week 4** | **7** | The focus on a **square shape was something the children were all comfortable with.** Also having the drawing options their too.<br>The educators were comfortable too as learning about **shapes are part of the curriculum.** | Play-Session 8<br>We decided to:<br>– Continue to make links between CT and the curriculum going forward<br>– starting with creating stories for mTiny – 'first this, then this' sequences – algorithmic thinking<br>– build on the children's understanding of programming / tapping forward and turn sequences to move mTiny – pattern recognition |
| | **8** | The children are **applying their learning/ CT skills** from play-session 7<br>We **didn't need to step in as much** to scaffold or guide the children<br>The **children persevered** more than before. | Play-Session 9<br>We decided to:<br>– Build on their learning/ extend their CT by revisiting programming mTiny to draw shapes<br>– this time a rectangle to increase the challenge. |

| | | | |
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| **Week 5** | **9** | **Lots of focus** on their **computational thinking** about how to programme mTiny. The children were **all at different stages of CT and understanding**. We could see they were **building on last week's learning** and understanding. Some children need much less assistance with CT concepts. | Play-session 10<br>We decided to :<br>– Consolidate their learning and CT skills over the last few sessions<br>– Continue with the focus for Play-session 8- co-creating stories for mTiny – 'first this, then this' sequences – algorithmic thinking, pattern recognition and debugging- finding and fixing mistakes. |
| | **10** | **Some children** are able to engage with coding and **programming mTiny without much assistance**.<br>Some children are **finding it hard** to focus and persevere. | Play-Session 11<br>We decided to:<br>– Return to the children co-constructing stories for mTiny.<br>– Focus on our pedagogical strategies to support each child at their level of CT understanding. Stepping in and back in response.<br>– Some children need us to step in more and some need much less assistance when engaging in CT concepts/ skills |
| **Week 6** | **11** | We noticed more chatting and talking out loud from the children -perhaps there CT understanding has developed and this felt more familiar to them like their regular play rather than learning something new.<br>The educators used verbal prompts rather than stepping in to assist. | Play-session 12<br>We decided to:<br>Follow the same plan as Play-session 11. Give the children more opportunity to build on their CT understanding and play. |
| | **12** | We are starting to see collaborative play and sharing thinking. Children are thinking about the sequence and finding and fixing problems, They set themselves that challenges. There is increased social play. | For out last debrief session<br>We reflected that:<br>Over the six weeks the children mostly explored how to use/ programme mTiny and what mTiny can do. For the last couple of play sessions the children appear to have progressed to integrating mTiny with their imaginative play- suggesting they have now developed foundational CT skills to do this. |

# Appendix Y: Educator CT Learning Prompts



## Supporting children's computational thinking

The educator has an important role in helping children to develop computational thinking skills.

These thinking skills include :

- Working out the steps needed to complete a task (Algorithmic Thinking)
- Arranging the steps in a logical sequence (Algorithmic thinking)
- Breaking larger steps into smaller steps (Decomposition)
- Spotting patterns from before that can be reused this time (Pattern Recognition)
- Finding and fixing mistakes and solving problems (Debugging)

The educator can support computational thinking using gestures, phrases, open-ended questions and prompts that encourage children to think more deeply.

The educator might:

- **Think out loud**, for example, '*I wonder what would happen if…*', '*I wonder how we can…*', '*oh, I notice…*', '*oh, something went wrong…*'
- **Ask open-ended questions**, for example, '*what might happen if …*', '*I wonder if there is another way to…*', '*Why do you think that?*'
- **Ask children for their ideas and opinions**, for example, '*what should we do instead?*', '*what do you think…*'
- **Remind children about things they have said or done before**, for example, '*do you remember when…*', '*does this remind you of…*',
- **Extend conversations**, for example, '*that sounds very interesting, can you tell me more?*'
- **Actively listen and respond** to children's verbal and non-verbal communication - language, gestures and actions.
- **Notice and narrate children's discoveries**, for example, '*oh, I can see…*'
- **Encourage children to think about the order**… first this, then this, then this…
- **Use gestures to draw children's attention** to something, for example by pointing, looking at the object and then looking back at the child to catch their attention, or by positioning their body to direct children's attention in a particular direction.

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