A Premature Step?

Searching for consensus on the integration of STEM in ECE settings in the Republic of Ireland

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For Seán, the best person I ever met, and Art, the best person I ever made.

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Abstract

Now a mainstay in educational policy, the term 'STEM' [science, technology, engineering, and mathematics] is often used, but frequently misunderstood. First appearing in the 1990s it has been common in economic and educational discourse ever since. Those working directly with children are at a loss to operationalise STEM education several decades after the term was first introduced. This is due, in part, to the fact that STEM is still considered an emerging field of inquiry and consequently, pedagogical approaches and conceptual models remain undertheorized. In parallel, EC pedagogy and curriculum are insufficiently conceptualised, posing practice and policy dilemmas of their own. In the Republic of Ireland, STEM is becoming more prominent in early education policy, appearing in inspection criteria, curricula, and limited professional development provision. What is absent from the same policy is a clear conceptualisation of EC STEM or a plan for its implementation in this context. This study explores expert opinion about how EC STEM should be defined and understood, and the skills knowledge and dispositions early educators require to successfully support EC STEM in ROI. Findings indicate that understandings of EC STEM are still emerging, and little consensus is found even among EC STEM experts making the inclusion of STEM in policy a premature step.

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1.1 Introduction

This study is a response to a knowledge gap regarding STEM education in early childhood education and care (ECEC) in the Republic of Ireland (ROI). With many long-term and influential policy documents under development [including the workforce development plan; literacy and numeracy strategy; and updated curriculum guidelines for ECEC] STEM education features explicitly on the ECEC agenda for the first time. In the past decade the Irish state has published an unprecedented number of STEM education policy documents. Multiple STEM implementation plans, scoping reviews and evaluation documents have been released year on year since 2016 with exceptional influence. These far-reaching and expansive documents take a long-term view on developing STEM learning across the entire school system from early childhood to the end of post-primary and beyond. The aim is to make Ireland a leader in STEM education by 2026 (Department of Education and Skills (DES), 2017b). The State's overall focus on STEM education is likely to lead to a stronger STEM requirement in the core ECEC policy expected in the coming years. At the same time, the ECEC sector have reported their lack of confidence and knowledge in relation to STEM (Department of Education and Skills, 2020c; O'Neill, Gillic, & Winget-Power, 2022; O'Neill, Gillic, et al., 2023) and their STEM practice has been deemed unsatisfactory by Department of Education inspectors (Donnelly, 2022). While STEM is front and central on the educational policy agenda in ROI, there is a paucity of guidance about *how* this might be enacted, the skills and knowledge educators require, and how they might be supported in developing their self-efficacy in this relatively new area of ECEC. The underpinning research question for this study therefore, is ‘how should STEM education be implemented in ECEC in ROI?’

1.2 Study Focus

The motivation for exploring this topic is two-fold. Firstly, I am an ECEC lecturer in the Republic of Ireland who teaches EC STEM, technology and mathematics modules. In Ireland at least, this is a new area of practice. With very little empirical evidence and few educators with practical STEM experience, the implementation of EC STEM in ROI remains finite. Despite a small and active group who promote the use of STEM approaches and digital technologies (see O’Neill, Gillic, & O’Reilly, 2024) there is little national consensus on how *or if* these methods should be used in ECEC. In line with my own experience as an educator, manager and mentor in EC settings, my undergraduate students report resistance when attempting to enact their STEM learning on professional placement. EC educators with little or no STEM experience or education are in the majority in ROI (O’Neill et al., 2023). Therefore, policy that required a widespread introduction of EC STEM was unforeseen and unexpected.

Secondly, before taking up my role as a lecturer I worked in curriculum and policy development. I saw first-hand how choices are made about curriculum direction and worked closely with those in senior positions who made these decisions. In my time in policy, I found that 1) decisions are made without making accommodations for ECEC and its unique traditions, structure and workforce; 2) ECEC was awarded far fewer supports, guidance and finance to carry out necessary actions related to policy / curriculum change when compared to other stages on the education continuum; 3) the ECEC sector was consulted in a limited fashion, due in part to the fragmentation of the ECEC sector which developed without state oversight and; 4) those making decisions are small in number and those with any legitimate early childhood expertise are even fewer in number again. As such, decisions made often are done so without an understanding of how these choices might impact the ECEC sector as a whole, or indeed how decisions are likely to be perceived by educators.

1.3 Aims and Research Questions

The aim of this study is to explore current conceptualisation of Early Childhood Science, Technology, Engineering and Mathematics (EC STEM) and to gather expert opinion about how it should be defined and could be implemented in ROI. Key to this approach is the consultation of multiple stakeholders including educators working directly with children, those in mentoring and support roles, those in lecturing and research roles, as well as those in policy and curriculum development within the ROI and beyond. A surprising variation in understanding exists relating to the purpose, structure, and goals of STEM education due to the absence of a uniform conceptualisation of STEM in the field of education (Jamil et al., 2018; Palmér, 2019). As such, there is no clear consensus on how ECEC educators are expected to integrate STEM disciplines and processes into their curriculum, and the type of teaching practices suitable for young children.

Thus, the following research questions are explored in this study:

- How should STEM education be implemented in ECEC in Ireland?
- How is it defined and understood?
- What key skills, knowledge and dispositions do ECEC educators require to meaningfully support EC STEM?
- How could / should educator capacity in relation to EC STEM be enhanced?
- What professional development opportunities do educators need to meaningfully implement STEM in ECEC settings?

It should be noted that the term STEM is used throughout this thesis. This term is chosen to reflect the terminology most often used in State documentation but does not signify a preference for this term over any other. Similarly, the term dispositions is used to reflect this terminology in ECEC curriculum and workforce development documentation in ROI.

1.4 Defining STEM

STEM education is de rigueur. Over the past two decades it has become more prominent in international discourse in industry and innovation, education, and competition (Beylis et al., 2023; Cunningham & Villaseñor, 2016; European Commission, 2023; Munoz Boudet et al., 2021; Museus et al., 2011; OECD, 2017, 2018, 2021a; Schomer & Hammond, 2020; Sosale et al., 2023; Subasinghe et al., 2023; World Bank, 2017). Since the early 1990s, understanding of STEM has evolved and changed. Definitions were once concerned with the knowledge content, merely mirroring the content of its constituent parts but in the intervening years, the meaning of STEM has expanded to include an approach to problem-solving, application to real world issues, and the integrated use of knowledge across several learning domains.

There is imprecision in the use of the term 'STEM' (National Research Council, 2011; Tippett & Milford, 2017) and it has become a catch all phrase, leading to a general confusion about what STEM is, what it means for society at large and how it can be supported within educational contexts (Donahoe, 2013; Marrero et al., 2014). Different conceptualisations of STEM range from an acronym for the constituent disciplines of science, technology, engineering and mathematics, a pseudonym for science education, an umbrella term that refers to one or more of the STEM disciplines, or reference to interdisciplinary, multidisciplinary, or integrated approaches to teaching and learning. In addition, representatives from different settings including government, industry, education, and the media use this term with different connotations. With multiple agendas at play, different goals and implementation methodologies are to be expected (Siekmann & Korbel, 2016). These competing theories and agendas cause confusion and add to the complexity of integrating STEM subjects and enacting STEM in education settings (Kelley & Knowles, 2016). It follows then, that educators struggle with the complexities and issues emerging from this relatively new and ill-defined field (Barkatsas et al., 2018).

Hasanah (2020) has identified four key definitions to help frame understandings of STEM. These are STEM as a discipline, STEM as instruction, STEM as a field and STEM as career. These key definitions are outlined briefly in **Table 1.1.**

STEM as Discipline	STEM as Instruction	STEM as Field	STEM as Career
1. Related to discipline-specific content **2.** Relates to one or more discipline area **3.** In some definitions at least two disciplines will be integrated **4.** Most common definition in the literature	**1.** Stem as an approach to teaching **2.** Active, student-centred learning **3.** Common descriptions include; Inquiry, reasoning, digital learning, cooperative learning, hands on, 21st century skills, application to real life	**1.** STEM described as a broad field of study **2.** Disciplines include Science, tech, engineering, math but also natural science, data & computers, political science psychology, sociology & economics	**1.** Any career related to STEM disciplines **2.** Examples include molecular biology graduates working as scientists **3.** Integration in terms of STEM is uncommon

Table 1.1 – Key definitions of STEM education. Adapted from Hasanah, 2020

Decades after the term was conceived, the question of what constitutes *STEM* remains an issue for scholars, curriculum developers and educators (Fraser et al., 2018; Johnson et al., 2021; McComas & Burgin, 2020).

1.5 Structure of the Thesis

The thesis is presented in six chapters. *Chapter On*e introduces the study, provides a brief rationale, and discusses aims and research questions. *Chapter Two* explores current literature pertaining to EC STEM that provides context for the study, including evolving STEM definitions; drivers of STEM educational policy; STEM and issues of social justice; and contemporary EC STEM debates. Also included in this chapter, and more closely linked to the research questions, are discussions about conceptualisations of EC STEM, educator's beliefs, attitudes and knowledge regarding EC STEM, and issues of professional development.

Chapter Three explores the early childhood policy context in the Republic of Ireland, framing the unique issues that impact the sector and that may influence the successful implementation of STEM policy. This includes rapid change in the sector over several decades, issues arising from the market model and a lack of coordination, funding and unduly burdensome financial, inspection and compliance systems. *Chapter Four* outlines how methodological decisions were made to form a congruent approach with the underpinning ontology/epistemology of the study. It provides a rationale for the paradigm employed; the approach to generating and analysing the data; the research design and methods utilised. *Chapter Five* combines findings and discussion of these findings under a number of themes. The discussion includes an explanation of dissent among the expert group, highlighting disagreement and compromise. Finally, *Chapter Six* identifies study conclusions, and recommendations for future research.

Chapter 2 – Literature Review

Chapter 2 – Literature Review

2.1 Introduction

This chapter explores current literature pertaining to EC STEM that provides context for the study including evolving STEM definitions; drivers of STEM educational policy; connections, or lack thereof, between STEM and Early Education content and pedagogy; STEM and issues of social justice; and contemporary EC STEM debates. More closely linked to the research question are discussions about conceptualisations of EC STEM, educator's beliefs, attitudes and knowledge, and issues of professional development which are situated at the end of this chapter.

2.2. Changing Definitions of STEM

Acronym	Definition	Explanation
STEM	Science, Technology, Engineering and Mathematics	Often used to refer to learning across any STEM discipline area More recent definitions imply a connection across the discipline areas to create knowledge as a whole
STEAM	Science, Technology, Engineering, The Arts, Mathematics	An extension of STEM incorporating 'the Arts' as a fifth discipline. STEAM definitions have a stronger focus on the approach rather than content or discipline knowledge.
I-STEM	Integrated Science, Technology, Engineering and Mathematics	Any integrated instructional blending of the four disciplines (or combination of two or more disciplines)

Table 2.1 Summary of STEM Definitions

Originally, the term STEM referred to learning across *any* STEM discipline area, with mathematics and science dominating. Teaching and learning related to the individual disciplines remained separate and subject specific (i.e. STEM as Discipline). More recently, the definition of STEM has evolved to the point where it is considered a meta-discipline, linking the domains of science, technology, engineering, and maths to create knowledge as a whole (Kennedy & Odell, 2023). Current theories conceptualise STEM education as transdisciplinary and holistic (SEADAE, 2020) and imply integration between some or all of the disciplines. Strong discipline knowledge is expected, as well as an understanding of processes and practices from each subject area. Some conceptualisations of STEM education even include metacognitive skills such as communication, problem solving, creativity, critical thinking, and collaboration as expected outcomes (Fitzallen & Brown, 2017).

In addressing education policy and curriculum, STEM typically refers to an integrative approach to teaching and learning (Belbase et al., 2021; Wan et al., 2021; Zendler et al., 2018). In this instance, the term STEM refers to not only discipline content knowledge but also implies a certain pedagogical approach [i.e. STEM as instruction]. As part of this approach, academic concepts are applied in real-world scenarios and authentic problems are used to challenge students to make connections between theory and practice. Scientific enquiry, engineering design, mathematical analysis and problem solving foster the development of 21st century skills leading to a rigorous academic environment (Johnson, 2012; Quigley et al., 2017; State Education Agency Directors of Arts Education, 2020).

A recent scoping review (MacDonald et al., 2024) pertaining to EC STEM found similar issues in uncovering a clear STEM definition. The study found that different characterisations of STEM were evident across the papers reviewed (22 in total) and that integration of the four STEM disciplines was rarely referred to in an explicit way. The authors concluded that the evidence base for early childhood STEM remains small, impacting the validity of any conclusions drawn in their study (Mac Donald et al., 2024). The implications of this are addressed later in this chapter.

2.2.1 STEAM and I-STEM

The terms STEAM [science, technology, engineering, the arts and mathematics] and I-STEM [integrated STEM] also appear in the literature, each implying a slightly different focus. STEAM is considered as an extension of STEM, with the former incorporating 'the Arts' as a fifth discipline. STEAM definitions have a stronger focus on the approach rather than content or discipline knowledge and could be classified as STEM as instruction. It highlights elements such as the use of exploratory approaches, the inclusion of authentic problems that encourage problem solving, and the integration of disciplines (Quigley et al., 2017; State Education Agency Directors of Arts Education, 2020). Experiential learning, collaboration, creativity, risk taking, and persistence are promoted; skills considered necessary for future leaders and economies (Barkatsas et al., 2018; Belbase et al., 2021; Burnard & Colucci-Gray, 2019). In ECEC, STEAM integrates and uses the arts in the STEM curriculum to help children learn about and express STEM concepts. It has been argued that adopting a STEAM approach in ECEC is a better way to support educators to feel comfortable with the basic elements that comprise STEAM (DeJarnette, 2018; Johnston et al., 2022; Sharapan, 2012). STEAM encourages children to understand the world around them, expands on children's interests, encourages, and appreciates children's questions, and helps children to begin to see the world in a STEM way. This, it could be argued, is more reflective of ECEC curricula and approaches and may lead to educators embracing STEM more readily. However, a more recent scoping review pertaining to EC STEM found that different views and definitions of STEM continue to be evident across studies, with very few explicitly describing the integration of the four STEM disciplines (MacDonald et al., 2024).

Issues pertaining to the definition of STEAM and its adoption in education settings exist. For example, Burnard and Colucci-Gray (2019) maintain that when referencing 'the arts' meaning varies and can encompass specific forms of visual arts (sculpture, painting, drawing, design, textiles), performing arts (music, drama, dance, and theatre), craft and design, and digital arts (animation, photography, illustration, video, and film) widening even further to include the liberal arts and humanities. The arts are a vast field, much like STEM. The merging of these two broad concepts into a third leads to a higher likelihood that 1) the educator will not possess expertise in all constituent disciplines (science, technology, engineering, mathematics, visual arts, performing arts, craft and design and digital arts) and 2) that core concepts and skills risk being lost. Indeed, early childhood educators report significant anxiety around their capacity to engage in and support the arts in their practice (Probine, 2023). Thus, could the addition of another discipline hinder EC STEM pedagogy further by adding teaching burdens and requiring more professional development (PD)?

Integrated STEM, or I-STEM, promotes the inherent connectivity of the four disciplines as compared with teaching disciplines in silos (Fraser et al., 2018; Reynante et al., 2020). I-STEM can be defined as any integrated instructional blending of the four disciplines (McComas & Burgin, 2020b) however some propose that the incorporation of two or more disciplines can be considered integration [more on this below] (Johnson, 2012; Johnston et al., 2022; Kloser et al., 2018). The level of integration required is what is contested within this definition. More detailed definitions require that the problems posed in I-STEM must pose real-world challenges that have more than one answer and can enhance student learning (Hourigan et al., 2022; Kelley & Knowles, 2016; Moore et al., 2014). I-STEM is both a curriculum and pedagogy and therefore needs consideration of what to teach and how to teach it (Hourigan et al., 2022; Margot & Kettler, 2019). Thus, it can be defined as STEM as Discipline *and* STEM as Instruction (Hasanah, 2020).

2.2.2 Integrated STEM Frameworks and Application

For some, integration of disciplines is vital in STEM education and models exist to rate and critique the level of integrated STEM practice. Factors such as the number of disciplines addressed, the concepts and skills developed, and whether real world applications are employed are often cited. For example, in their framework, Moore et al (2014) list six factors for consideration that should be present when integrating STEM with young children: 1) child-centred pedagogy; 2) working as a team; 3) inclusion of math/ science content; 4) using iterative engineering design processes; 5) learning from mistakes; and 6) situating experiences in engaging contexts. One can see how this could be a useful starting off point to ensure that required factors of integrated STEM are being adopted. However, a deep understanding of each of these factors is required for Moore et al.'s framework to meaningfully impact practice. I argue that, in general, EC educators would find some of these factors easier to execute than others. Maths and Science content, and engineering process are not common in EC educator initial education or in-service training (O'Neill, Gillic, et al., 2023; O'Neill, Gillic, & Kingston, 2022; Sheridan et al., 2009; Wan et al., 2021), so this lack of content and pedagogical knowledge would need to be addressed *before* Moore et al.'s (2014) framework could be adopted.

In contrast, Vasquez et al. (2013) use a continuum to describe the degree of integration between disciplines, an overview of which is provided in **Table 2.2.** At the lowest level (disciplinary) content and skills related to each individual discipline are taught separately. At the next level (multi-disciplinary), common themes connect skills and knowledge from two or more disciplines, but these continue to be taught separately. At the third level, (interdisciplinary integration) knowledge and skills learned from two or more disciplines are closely linked to deepen knowledge. At the highest level of integration (transdisciplinary) real world problems are used to apply knowledge or skills from two or more disciplines.

	Level	Description of Pedagogy
1	Disciplinary	Knowledge and skills from individual STEM disciplines are taught separately.
2	Multi-disciplinary	Common themes connect knowledge and skills from two or more disciplines. These continue to be taught separately.
3	Interdisciplinary Integration	Knowledge and skills learned from *two or more* disciplines are closely linked.
4	Transdisciplinary	Real world problems are used to apply knowledge or skills from *two or more* disciplines.

Table 2.2. Vasquez et al.'s (2013) Continuum of Integration between Disciplines.

Considering Vasquez et al.'s framework (2013), the progression from disciplinary to transdisciplinary integration requires multiple stages. This implies that the integration journey is lengthy, and that educators need to 'build-up' to the application of STEM to real world problems. One can see how this circles back to difficulties with defining I-STEM. If the application to real contexts is part of this definition, according to Vasquez et al.'s continuum, deep levels of understanding regarding knowledge and skills, *and* proficient pedagogy are needed on behalf of the educator.

2.2.3 STEM Education and Teaching

Without clear guidance about what to teach or how to teach it is understandable that educators are unsure how to proceed. Siekman and Korbel (2016) argue that definitions of STEM skills are inconsistent and not specific enough to inform education and skill policies, leading to unsuitable and uncoordinated responses. In an attempt to clarify these definitions, they argue that multiple definitions, or at least a number of STEM categories are required to be more specific and consistent. Only then, they argue, can the definitions meaningfully inform education and skill policies leading to effective and substantial responses.

The STEM acronym may be widely recognised but its meaningful application or enactment in educational context is poorly understood, leading to confusion for educators (DeCoito & Myszkal, 2018; Fraser et al., 2018). In fact, what constitutes good STEM teaching has been described as *muddled* (Marrero et al., 2014). Perhaps this relates to the requirements to support STEM skills, knowledge, and dispositions, some of which are subject-specific and some more broad. STEM teaching incorporates procedural and discipline-specific knowledge; epistemic knowledge about the disciplines such as knowing how to think like a mathematician or scientist enables students to extend their disciplinary knowledge; and procedural knowledge, acquired by understanding how something is done or made; some of this is domain-specific, some transferable across domains supported through practical problem-solving, systems thinking and design thinking (OECD, 2018).

The lack of agreed definition relating to STEM content and implementation cause difficulties when operationalising STEM education (van Driel et al., 2018). Firstly, STEM is not a subject. In post-primary and tertiary education, disciplines are taught separately by educators who specialise in one or more of its constituent parts, science, technology, math, and engineering. Each discipline has its own core concepts and associated skills, which differ from subject to subject. Secondly, as disciplines are bound together under an umbrella term, concerns arise about watering down subject content, and/ or the loss of concepts and principles crucial to the integrity of each individual discipline. The prominent position of STEM in educational policy and discourse has the potential to diminish the importance of individual disciplines or discipline content. The dominance of STEM in political circles and corresponding policy has led to some early childhood academics to express concern that mathematics will become a servant of science, technology, and engineering, only appearing when needed to support other disciplines (Katz, 2010; Thiel & Jenssen, 2018). The adoption of mathematical strategies and processes fosters an approach to thinking and reasoning useful in early childhood and beyond (Katz, 2010). In early childhood, maths talk has been identified as a key strategy in supporting young children's fundamental maths skills and early meta-cognition (Dooley et al., 2014). Opportunities to support learning may be lost if discipline-specific content and processes are lost to STEM. Finally, the focus on metacognition and transdisciplinary skills such as problem solving or thinking critically has the 'potential to devalue disciplinary knowledge and pose difficulties for educators in the appropriate balance of knowledge and skills' (van Driel et al., 2018, p. 33). Thus, STEM teaching includes many moving parts and requires extensive skills and knowledge as well as excellent pedagogy.

2.2.4 Defining Early Childhood STEM

A clear definition of EC STEM is required to agree terms for enacting STEM educational policy. Once established, a definition can inform curriculum and pedagogy in early childhood and support a more integrated pedagogy where all four STEM disciplines are enacted in ECEC education experiences (Campbell et al., 2018). Hasanah's (2020) definition goes some way toward providing more exact definitions or characteristics of STEM. See **Table 1.1** for details.

Recent scoping reviews and meta-analyses shed some light on how EC STEM could be defined. For example, Wan et al.'s (2021) study suggests that STEAM is gaining popularity in the EC context due in part to its emphasis on creativity and design thinking (Sharapan, 2012). Investigating STEM, STEAM, and makerspaces for children from birth to eight years Johnston et al., (2022) found that STEAM was deemed more applicable to practice and learning in ECEC; EC STEM literature had a stronger focus on one or two specific disciplines, where STEAM literature highlighted the integrated and embedded nature of STEAM in children's everyday experiences. Elsewhere it has been argued that young children experience STEM in an integrated way as part of their everyday lives and as such, from birth they have already been exposed to some of the ideas, understanding, knowledge, and skills of STEM (Campbell & Speldewinde, 2022). In their study STEM was described flexibly, acknowledging that it could include 1) all or some of its constituent disciplines, and/or 2) refer to the development of inquiry skills and thinking capabilities, and conclude that either are relevant in ECEC settings (Campbell & Speldewinde, 2022).

The distinctions identified by Johnston et al., (2022), Campbell and Speldewinde (2022) and Wan et al. (2021) are akin to those pertaining to 'mathematics' and 'numeracy'. Mathematics is a knowledge domain, whereas numeracy acknowledges the socio-cultural perspective required to identify, think about, and apply math in our everyday lives (Dooley et al. 2014). It emphasises the context, purpose, and usefulness of maths in solving problems and encourages the meaningful application of mathematical concepts (MacDonald et al., 2018). In the same way that numeracy implies a particular application, a more specific term for EC STEM that reflects the integrated nature of learning and the emphasis on thinking, inquiry and creativity in early childhood settings could present an opportunity to be more precise in our language, as recommended by Siekmann & Korbel (2016).

Having reviewed a number of STEM definitions related to EC STEM ((Donahoe, 2013; Johnson, 2012; Johnston et al., 2022; Kloser et al., 2018; Moomaw, 2014; Tippett & Milford, 2017) the factors that appear frequently are:

- Integrated in nature.
- Two or more discipline areas included.
- Authentic problems/ application to the real world.
- Incorporates discipline concepts and approaches.
- Reflective of children's lives.

By way of example of integrated STEM in early childhood, Katz (2010) describes a scenario where kindergarten children investigated the properties of a collection of balls donated by their family members, including: a basketball, beach ball, bowling ball, football, golf ball, ping pong ball, marbles, billiard ball, tennis ball, and a world globe. According to Katz (2010), the project raised questions that supported many opportunities for the introduction of integrated STEM concepts, dispositions and processes, an overview of which is provided in **Table 2.3.** Katz argues that it is this type of approach, iterative and lengthy, that supports integrated STEM learning with young children. Ideas build over time reinforcing children's growing understanding and knowledge about a topic.

Prompt/ Idea	Investigation/ Discussion	Sample STEM disciplines and ideas supported
Was the world globe a 'ball'?	A discussion of roundness and the concept of "sphere" and the term "spherical" was introduced	Science, mathematics, logic and reasoning
Is something considered a ball if it does not bounce?	The globe, bowling ball and the marbles didn't bounce. Children categorised spheres according to whether or not they bounced	Scientific approach, mathematics
What is inside each ball?	What might be inside the balls based on weight and other properties, introducing concepts of solid, hollow, empty, full	Scientific approach, mathematics, logic and reasoning, developing hypothesis
How far will each ball roll?	Using a slope made from a large block and a plank the children measured the length the balls rolled depending on the steepness of the plank and the surface e.g. carpet, wooden floor, gravel outside	Scientific approach, mathematics, logic and reasoning, developing hypothesis, engineering, use of technology

Table 2.3. Example of integrated STEM in EC settings. Adapted from Katz, 2010

2.3 Emergence of STEM in Educational Policy

The recent deluge of STEM policy is a response to complex global social, environmental, economic, and political factors. STEM has been positioned as a panacea to many of the world's ills. Climate change, increasing natural disasters, diminishing biodiversity and the fallout from the recent COVID-19 pandemic require creative and innovative STEM responses (OECD, 2021a). The transformative technologies, medical advancements, transnational collaboration, and shared discoveries attributed to STEM, can contribute positively to a viable environmental and social future *and* sustainability for the planet. Decades of policy also position STEM as fundamental to future economic prosperity, international competitiveness, and productivity (International Study Center at Boston College, 2019; OECD, 2015, 2019). To achieve these goals, a reliable supply of entrants into the STEM workforce is required. However, figures suggest that numbers studying STEM disciplines and entering STEM professions are declining (Department of Education and Skills, 2022; Kyoung Ro et al., 2022; OECD, 2021a). The main impetus of STEM policy is to provide twenty-first-century skills for the future economy and jobs market, to use natural and other resources ethically (Belbase et al., 2021) and to tackle inequity.

Equity and social justice issues are connected to STEM. Educational attainment is one lever that can increase opportunity for economically disadvantaged families, and increased access to STEM can create career opportunities to overcome deprivation (Rozek et al., 2019). The underrepresentation of women, and ethnic and social minorities in STEM fields and careers appears to be a concern for policymakers and academics for several reasons. Firstly, the inclusion of more diverse workforce in STEM will include a wider range of voices and will result in solutions that are applicable to a wider cross-section of population, while maintaining a society that consists of diverse and global communities (Buck et al., 2020; Jong et al., 2020). Secondly, due to higher salaries in STEM professions broadening participation in STEM can address gender-, race- and ethnicity- based income inequality (Museus et al., 2011). Thirdly, the participation of minority persons in STEM can ensure the well-being of people in minority communities and realise ethical obligations to remove damaging inequities that have persisted (Jong et al., 2020).

The following sections outline the multiple drivers for the inclusion of STEM in education policy, including preparing tomorrow's workforce for the unknown problems of the future, the standardisation of EC curriculum, curriculum standards and prioritising 'quality', and finally the role of STEM in social justice, equity issues, and gender disparity in education. Where possible, connection will be made to how this discourse might impact the implementation of EC STEM.

2.3.1 Future Making Education

> 'Economic, political, educational, and world leaders and organizations support STEM-focused teaching as a way to increase academic rigor in schools and introduce students' skills and knowledge that are of growing importance to tomorrow's workforce.' (Quigley et al., 2017, p. 1)

One driver of the STEM agenda is future proofing against the environmental and social impacts of the twenty-first century that could jeopardise global security and economic stability (Kelley & Knowles, 2016). Issues such as climate change, food and water security, biodiversity decline and the opportunities provided by technological advances, require greater competencies in STEM disciplines (OECD, 2021a). Complex global issues need creative solutions and STEM has been positioned as 'future making education' that stimulates thinking and innovation, enabling creative responses to ongoing challenges and allow citizens to navigate their way through the technological world that exists today (Belbase et al., 2021; Burnard & Colucci-Gray, 2019; Marrero et al., 2014). The last ten years has seen an intensification of the role of STEM as a vehicle for future-oriented thinking and planning. It is argued that by engaging in rich STEM experiences, students develop a range of generic skills and ways of thinking that enable entrepreneurial and innovative behaviours such as open-mindedness, creativity, problem solving, critical and logical thinking, communication skills and higher order skills in research and quantitative analysis (Fitzallen & Brown, 2017; Fraser et al., 2018). A key argument in the proposals for STEM education is that it produces critical thinkers, scientifically literate professionals and citizens, and enables the next generation of innovators to tackle problems of the future (Belbase et al., 2021; Erduran, 2020).

The complex global issues we now face require education systems to reach beyond simply helping students achieve high scores in mathematics and science through prescriptive ideas (Kelley & Knowles, 2016), but to be able to apply this learning in innovative and creative ways. Consequently, STEM education policy continues to increase (Johnson, 2012; Kelley & Knowles, 2016; Quigley et al., 2017). And yet, agreement about how the capabilities promised through STEM education are best achieved, remain elusive (Honey & Kanter, 2013).

2.3.2 The Standardisation of Early Childhood Education

Much STEM policy has futures-focused overtones. Accounts of expanding the STEM-capable workforce, increasing training and careers in STEM fields, and enhancing scientific literacy amongst the general public are common, even within EC (Tippett & Milford, 2017). The narrative of preparing children for their distant future careers, presents a limited view of early education. From this standpoint, ECEC is no more than a site for preparing children for later life, and future proofing society. According to Biesta (2009) narrow views about what young children are meant to accomplish in education results in an overt focus on academic achievement rather than a *good* education. Within this discourse of performativity and normativity, the purpose of education is relegated to conforming with predetermined criteria (Moss, 2013). The aim is to produce children who are ready to learn, ready for the next stage of education or ready to be a good neoliberal worker who is flexible, competitive, and responsive to market demands (Moss, 2016).

In contrast, ECEC traditions suggest that it should be seen as a public good and an important part of the education process (Bennett, 2013; Dahlberg et al., 2013; Hayes & Urban, 2018a; Moss, 2013, 2015). In the past, ECEC social-pedagogy traditions introduced children to the world, encouraged positive attitudes to learning and fostered positive social dispositions (Moss, 2013). This holistic approach to learning emphasized children's broad interests and development, and knowledge originated primarily from relationships and children's personal interest (Bennett, 2007, 2013). The prevalent idea was that cognitive development would be fully supported by encouraging the initiatives and meaning making of children (Bennett, 2013). This approach is still relevant today and is present in many ECEC settings in the Republic of Ireland. However, the scattered development of the ECEC sector and lack of coordinated approach to ECEC in ROI has led the government to a more and more on evaluation, inspection, and compliance as a way of leveraging control (Hayes & Urban, 2018b; Urban, 2019). Bennett (2013) illustrates a holistic model of pedagogy that acknowledges that all parts of a child's life are interconnected, and where concepts of care, learning and upbringing are brought together under one practice. Rather than achieving a pre-specified level of knowledge or ability in ECEC education, the aim of *this* type of education was to foster confidence in children's own learning, and a desire and curiosity for further learning. This is the type of early education I studied, practiced, supported, and believe in.

2.3.3 Prioritising 'Quality'

The globalisation of education has advanced the standardisation of teaching and learning across the world (Biesta, 2009, 2015; Moss et al., 2016; Sellar & Lingard, 2014). An increased focus on literacy and numeracy; high stakes testing and accountability; prescribed curricula; increased control over teachers and lack of professional autonomy, is evident (Wasmuth & Nitecki, 2017). Early education is not immune to these shifts in educational discourse and changing expectations of children's learning and achievement. International comparative testing concentrates on academic achievement in select number subject areas encompassing reading, maths, science, and problem-solving competences (OECD, 2023). To compete globally and move up in the ranking, policymakers focus more and more on core subjects. Improvements in literacy, numeracy and natural sciences are elevated to prime objectives and indices of education reforms (Sahlberg, 2015) which in turn leads to curriculum narrowing and, it could be argued, the reason for the elevated position of STEM in EC education policy.

While comparative testing is primarily directed at the middle teenage years, it influences the way EC education is shaped and researched. Downward pressures on early childhood education from international comparison are inevitable and have been a major influence on emerging notions of schoolification (Ang, 2014). As governments apply 'accountability pressure' (Little & Cohen-Vogel, 2016, p. 3) predetermined outcomes specified in curriculum documents have become increasingly important in EC policy (Grieshaber et al., 2021). The OECD's prime position in administering much of this testing places education in a neoliberal light where the focus is on money, success, evidence, and competition (d'Agnese, 2015). Indeed, in 2020, OECD released the first results of the International Early Learning and Child Well-being Study after testing 7000 five-year-olds, in a limited number of OECD countries across four early learning domains, 1) early literacy and numeracy skills, 2) self-regulation, and 3) social and emotional skills (OECD, 2020a). Heavily criticised by many in ECEC (Carr et al., 2020; Mackey et al., 2016; Moss et al., 2016; Moss & Urban, 2020), this approach is a considerable shift away from holistic development and integrated nature of children's learning presented above. Attention on standards, conformity, and imperfect conceptions of 'quality' will lead to the erosion of EC as a discrete and valuable form of education and play based pedagogy will inevitably give way to a pedagogy of compliance, a re-emergence of rote and directive learning, and a push-down formalised curriculum (Moloney, 2017). It also serves to undermine the expertise of EC educators whose role is limited to meeting standards and submitting to directives based on flawed ideological assumptions about ECEC (Oosterhoff et al., 2023; Stremmel et al., 2015).

Much like the curriculum narrowing in compulsory education, the concept of 'quality' in EC limits educational possibilities. A universal, objective, and stable ideal of 'quality' in ECEC is not possible or desirable (Dahlberg et al., 2013). The concept of excellence in ECEC assumes that experts can identify and assess *general* standards of 'quality' and therefore a setting evaluated as conforming to these standards is excellent. Who sets the standards and how are they applied is not subjective. Quality is a constructed concept that 'is neither neutral nor self-evident, but saturated with values and assumptions' (Moss, 2015, p. 10). Moss argues that trying to turn 'quality' into a subjective, value-based concept is futile. Nevertheless, it is a tempting model for policy makers as it supports the notion that universality, objectivity and certainty is possible in ECEC and the application of expert-derived templates, rating scales, checklists and standardised inspection procedures will inevitably lead to better outcomes (Moss, 2015). It is into this space that EC STEM enters.

2.4 Early Childhood and STEM

Against the backdrop of an ever-increasing focus on STEM, both STEM education and early childhood education have been at the forefront of national discussions in educational policy (Early Childhood STEM Working Group, 2017; Hourigan et al., 2022). EC STEM reports and guidelines are abundant (for example, Early Childhood Australia, 2018; Early Childhood STEM Working Group, 2017; Edwards et al., 2018; Hadani & Rood, 2018; McClure et al., 2017; Pasnik & Hupert, 2016) and there has been a marked growth in research and policy relating to EC STEM since 2016 (Donohue, 2019; Johnston et al., 2022; MacDonald et al., 2024; Wan et al., 2021).

Features of STEM education and ECEC are compatible and elements including the importance placed on play, exploration, investigation, observation, and communication are similar (Çiftçi et al., 2022). 21st century skills in demand from the STEM industry are fostered by an integrated approach to learning that is characteristic in ECEC settings (Donohue, 2019). Far from formal content knowledge and teaching that may be considered a requirement for STEM disciplines, an attitude of mind and characteristic ways of thinking guide practice in EC STEM (Speldewinde & Campbell, 2023). For example, sharing curiosity, asking questions, encouraging speculation and discussion, and devising simple enquiries (Katz, 2010). When using this approach, a clear connection can be seen between STEM and emergent and enquiry-based practice and curricula that are common in ECEC settings in ROI (NCCA, 2023a). Descriptions of effective STEM approaches and outcomes, mirror those of ECEC. Supporting curiosity about their world, knowledge, and processes inherent to STEM disciplines, and the undertaking of authentic investigations that use critical and creative thinking, sit well within the children's free-play explorations in ECE (Department of Education and Training, 2017; Early Childhood STEM Working Group, 2017; Yelland & Waghorn, 2020). The following sections focus on why and how STEM could be integrated into EC environments. It problematises some of the narratives that exist and suggests potential pitfalls in adopting STEM methods and content in EC settings.

2.4.1 STEM and Early Childhood Outcomes

Positive learning dispositions listed in the Irish National EC Curriculum framework (NCCA, 2009) include communication, collaboration, critical thinking, problem-solving, creativity, curiosity, adaptability, self-awareness, grit, resilience, persistence and playing well with others. These are almost identical to STEM skills highlighted by OECD (2021c, 2021b, 2021a). While not the aim of ECEC, provision of STEM has positive academic outcomes for children, which has significant implications for the provision of EC STEM. Generally, EC STEM appears to have positive effects on children's learning and development (Bers et al., 2018; Blum-Ross et al., 2020; Dandy et al., 2018; Hatzigianni et al., 2020; Lippard et al., 2019; Yücelyiğit & Toker, 2021). It establishes prerequisite and foundational skills that support content knowledge in later education such as scientific inquiry, number sense, critical thinking and problem-solving are shaped during children's earliest years (Aldemir & Kermani, 2017). These early skills are predictors of later achievement and interest in STEM. For example, it has been found that science achievement gaps begin in the early years, persist if unaddressed, and are largely modifiable in ECEC (Morgan et al., 2016). Early foundations in science are linked to the eventual achievement of science literacy for adults (Watts & Salehjee, 2020) and significantly higher enthusiasm and motivation for science in later life (Oppermann et al., 2018). This underscores the importance of early STEM for the development of children's STEM identity, motivational beliefs, self-confidence, as well as skills and knowledge.

Research indicates young children have an interest in and aptitude for mathematics (Christodoulou et al., 2017; Evans & Gold, 2020; Johnston & Degotardi, 2020; Papandreou & Tsiouli, 2020; Wang & Feigenson, 2019). Early exposure in real-life environments that enable children to apply mathematical learning positively impacts the mathematical readiness, attitudes, and competence of young children (Williams et al., 2021). What's more, early math skills are deemed more important than literacy or social and emotional skills in predicting later academic achievement, regardless of the child's gender or socioeconomic background (Duncan et al., 2007).

Unlike other STEM disciplines, technology is not a content area to be studied by young children, but a tool to support learning (Waite-Stupiansky & Cohen, 2020). In the right conditions, digital technology use in EC can lead to digitally amplified practice (Fleer, 2019b) enriching the play experiences of children and enhancing EC practice by providing a variety of complementary opportunities to transform existing curricula (Fleer, 2019b; Mantilla & Edwards, 2019; Masoumi, 2015). It can enable learning across STEM subjects in ways that may not otherwise be possible. Further, the use of technology in ECEC reflects many children's lived experiences with technology (Arnott, 2017) in which they are fluent and regular users (Yelland & Gilbert, 2017). Exciting and novel concepts of play have emerged as technologies are used within the frame of play-based pedagogical approaches (Gray & Palaiologou, 2019), for example, post-digital play, where children move seamlessly back and forth between digital and more traditional play materials such as blocks, sand, water, and creative materials.

Research on EC engineering, though less abundant (Lippard et al., 2017; Moore et al., 2018), indicates that engineering provides a foundational, cross-disciplinary link that contextualises STEM learning in EC (English & Moore, 2018). Engineering thinking helps children to move beyond simply solving problems, emphasising a level of intentionality and motivation in their action (Fleer, 2000). For example, the use of the BEST engineering design model (NASA, 2023) provides simple steps that allows children to

1. discuss what problem has arisen in play that they would like to solve e.g. making a shed for the small world animals,
2. identify constraints, for example, limited materials (blocks, cardboard, tape, scissors, markers), space (block corner), or time (until the end of free play)
3. research and plan their design, supported by discussion of ideas or by looking at examples in books or online.
4. build and test the shed and make sure it works. For example, will all of the animals fit? Are the entrances big enough for the animals to enter and exit? can all children comfortably play with the new shed?
5. Improve their design based on testing and further discussions.

The iterative design process provides a clear framework to support educators with STEM teaching (Ata-Aktürk, 2023; Eckhoff, 2021). The frame is useful in developing ideas *with* young children that make the most of their interests, capabilities, and funds of knowledge in natural extensions of purposeful play. Further, engineering habits of mind, for example, improving, adapting, and creative problem solving are developed as children learn to 'make things that work' and 'make things work better' (Lucas et al., 2017). Offering children time to engage with STEM, while being supported through educator scaffolding, can foster the development of more general and overarching STEM skills such as observation, investigation, inference, exploration, questioning, justification, and reasoning (Campbell et al., 2018). Research suggests that, if approached in a suitably playful way, EC STEM could provide opportunities to engage young children in experiences that take advantage of their prior knowledge, interests and experiences *and* support children's understanding of fundamental STEM concepts (Campbell et al., 2018; Fleer, 2021; Katz, 2010; Speldewinde &

Campbell, 2023; Stephenson et al., 2021). In this way, the tenets of early childhood education and the importance of children's agency and play are respected.

2.5 EC STEM Debate

Regardless of the benefits for children from engaging with STEM outlined in the literature, there are ongoing debates about EC STEM that might impact ECEC educators' motivation to include STEM disciplines or processes in their practice. Discourse pertaining to play, its definition, how it relates to children's learning and agency, and how play is presented and shaped by curricula frameworks across the world, frames much of EC STEM debate. An important distinction about the approach and philosophy undertaken in ECEC, as opposed to later education, is the central place of play in EC philosophy and praxis. These discussions include questions about the changing role of the adult, the impact of supranational and international organisations, questions about what play is for. As Fleer points out, collectively these questions demonstrate 'a need for re-examining the relations between play and learning – empirically, theoretically and pedagogically' (Fleer, 2019a, p. 2).

Present in the narratives pertaining to EC STEM are debates about the introduction of more didactic pedagogical approaches and formal content via STEM, whether play and the child's agency may be sidelined by 'doing' STEM, and how safe and appropriate technology are for young children. Each of these debates requires context to understand why and how they impact EC STEM implementation, to better understand the implications for the research question 'how should STEM education be implemented in ECEC in ROI?'

2.5.1 Safe and Appropriate Technology Use

Screens and technology are not the same, but the two have become conflated. The discourse around the risks and negative impact of screen times on children have led to practice dilemmas in ECEC settings (Straker et al., 2018). Nobody wants to put children in harm's way, but ECEC education should reflect children's lives, funds of knowledge and follow their interests. Children now grow up in media-rich, digital environments and actively engage in the use of technology as part of their daily lives (Arnott, 2017; Dandy et al., 2018). This context changes the conditions for play. Exposure to digital devices influences children's daily experiences, interactions, and culture, but this fact is not often reflected in early childhood education settings, pedagogy or curriculum (Aubrey & Dahl, 2014; Chaudron et al., 2018; O'Neill, 2018). For STEM to be meaningfully enacted in ECEC, perceptions of technology and its use in play need to be reconsidered. The role of an educator involves a process of continuous learning and *unlearning*. Long- held and largely invisible ideas, beliefs, and practices such as the exclusion of technology from EC environments, require interrogation. Challenging the status quo in education settings is an enormously long and complex process (Cochran-Smith et al., 2020) but is required if beliefs are to be contested and changed.

Little is known about the emerging digital pedagogies of educators, as much of the dominant research is focused on benefits of, or negative impact on children (Fleer, 2020). Anecdotal evidence suggests that capacities of educators are limited, and digital play is rarely sustained in ECEC. The potential for learning that digital media, technology, and popular culture present is lost, as educators' adoption of devices and digitally supported pedagogical approaches lags behind that children's digital play practices at home or the wider world (Nuttall et al., 2015). Further, children's digital activities are not well understood by educators, and are rarely appreciated in ways that connect to curriculum content or develop children's competences (Siina, 2022). The arguments pertaining to the suitability of technology in ECEC trundles on. What is clear is that legitimate concerns for children's wellbeing, and an overabundance of caution are factors that can influence the use of technology in EC and can impact the implementation of STEM by association.

2.5.2 A Change in the Function of ECEC

ECEC has its own traditions and pedagogy that distinguish it from later education. These acknowledge the integrated nature of learning, the crucial role of context, and the importance of play (Hayes, 2019). The care of the child and provision for their well-being is paramount and is of equal importance to the child's cognitive development. Tradition dictates that ECEC uses hands-on materials in socio-constructivist environments, where educators observe and assess young children's freely chosen play (Edwards & Bird, 2017). Much of the critique of EC STEM is framed around the 'teaching' of content knowledge, which is counter to socio-constructivist theories common in ECEC. Play is the dominant medium for learning in ECEC settings in many countries, and there is consensus that pedagogy is child-centred, an approach expressed in practice by children choosing what to do during extended free-play periods (Bennett, 2007). When compared to this, the introduction of STEM is perceived as a change in the main function of ECEC, from providing children with care and holistic learning opportunities to preparing them for school (Fosse et al., 2018).

Taking into account the impact of educational policy discourse on EC curriculum, Wood and Hedges (2016) explore the ways in which curriculum, pedagogy, play and learning are now understood. They argue that the traditional emphasis on 'laissez-faire' approaches in EC, characterised by learning through play and exploration, paid little attention to disciplinary forms of knowledge i.e., science, technology, engineering, and mathematics. Through their analysis of multiple EC curricula, they have found that these laissez-faire approaches are weakening as 'school readiness' requirements and the 'need to justify economic investment by proving its effectiveness' (Wood & Hedges, 2016, p. 389) become more commonplace. This formalisation or academisation (Ang, 2014; Husa & Kinos, 2005) of ECEC settings has been noted in EC research, and poses challenges (Fleer, 2019d). Specifically, educators worry that an academic emphasis in EC will supplant attention from children's well-being; and that children's curiosity and intrinsic motivation to learn will be undermined by a push toward academic outcomes or performance (Stipek, 2013). Educators report apprehension about the changing focus in ECEC and continue to show a preference for more traditional pedagogical approaches (Schriever et al., 2020). A recent study found that schoolification of the sector is EC educators' most significant concern, as they believe play as a pedagogical tool is disappearing from settings in favour of school-like activities (Barblett et al., 2016).

2.5.3 The Relationship between Play and Learning

Much of the language used when describing play and learning is loaded with meaning. Ambiguity between the two and a need for further refinement is recognised in the literature (Baker et al., 2023; O'Síoráin et al., 2023; Sutton-Smith, 2009; van Oers, 2013). Play takes many forms and exists on a continuum, from child-initiated free play to adult-led activity (Pyle & Danniels, 2017; Zosh et al., 2017), the latter of which is organised and executed in a different way. Debate about how play is defined, what *type* or *form* of play is beneficial in EC and its impact on child learning outcomes has implications for pedagogy in EC. In EC 'learning' is positioned as adult-led, planned and organised with a focus on distributing knowledge (Pramling Samuelsson & Björklund, 2023). In contrast, play is characterised as intrinsically motivated, involving creativity and imagination and results in a meaningful experience for children. As such, play must include some level of agency where children take ownership and an active role (UNICEF, 2018). Below issues pertaining to terminology, a stronger focus on outcomes and undertheorized pedagogy are discussed to explore whether the difference between 'play' and 'learning' be reconciled within EC.

Terminology such as learning through play, 'playful learning' (van Oers, 2013), guided play, playful approaches, 'purposeful play' (Ministry of Education, 2012) are common, and at times, are used interchangeably in EC research. While the language used may be similar its use is imprecise and does not guarantee understanding of *meaning*. Findings of a scientific literature review carried out by Cheng and Johnson (2010) suggest the need for more careful use of the term play in early education and child development studies. Not least because the connotations of language choice, i.e. how language associated with play and learning is framed and employed by different stakeholders, frames understandings of play and positions the aim of EC in a particular sphere. These interpretations are, at times, difficult to detect as similar language is used to describe the varying pedagogical styles that educators may adopt with play often central in each conception.

The language used to describe play is a political tool, used with strategic intent (Wolfe et al., 2013). It can support the readiness agenda as the way play and EC are described though policy determines decisions about intentional teaching in EC (Grieshaber et al., 2021). Higher expectations for the production of academic outcomes in ECEC can lead to narrow interpretations of play based pedagogy (Pramling Samuelsson & Björklund, 2023; Pyle & Danniels, 2017; UNICEF, 2018). Claims that play has been 'hi-jacked' (Pyle & Danniels, 2017), or 'tamed' (Wood, 2014) by educational policy illustrates frustration and concern pertaining to the changing role of play in EC.

Play is an important element of ECEC, as evidenced by the wealth of scholarship and research on this topic. Across two studies, Cheng and Johnson (2010, 2008) reviewed 141 research articles pertaining to play, and concluded that play is a matter of great importance in EC and child development research and praxis throughout the twentieth century. But the relationship between play and learning is often taken for granted in both spheres (Pramling Samuelsson & Björklund, 2023). The concept of play, even within educational research, is often ambiguous and the implications of research findings unclear (Cheng & Johnson, 2010). Some argue that causality between play and learning cannot be inferred based on current evidence and go as far as to claim that research is tainted by play bias which is predisposed to find positive effects of play on child development (Lillard et al., 2013). The play ethos/ bias occurs because researchers in this area tend to believe strongly, a priori, in the value of play. Hence the research they conduct is 'tainted by a bias to find positive effects of play on child development, even when such effects may not exist.' (Weisberg et al., 2013, p. 35). Therefore, correlation data is reported as causal when empirical evidence to support this claim is sparse. As such, it is argued that a more scientific approach is required when researching play (Lillard et al., 2013; Weisberg et al., 2013).

Differing interpretations of play are evident in research, policy, and practice. The role of the adult and the level of influence or control is central to these debates. Dualistic binaries such as adult-led versus child-led or learning versus play, are particularly evident in EC but a simple dichotomy masks the complexity of EC curriculum and pedagogy (Hedges, 2022). Wood (2016) proposes three unique pedagogical styles that are commonly found in EC, 1) child-initiated play, 2) adult-guided play and 3) technicist/ policy-driven practice. These styles frame and problematise understanding of the different ways play is a mechanism for learning and pedagogy (Hedges, 2022). The differences between styles gives rise to variance in practice including, who initiates and leads activity, the purpose and style of interaction, the nature of outcomes, goals of the pedagogical style, what is assessed and how, and constraints of each style. Characteristics of each are outlined further **in Table 2.4.**

	Child-initiated Play	**Adult-guided Play**	**Technicist/ policy-Driven**
Degree of Structure	Limited by rules of the setting, choice of material and expected behaviour	Differs depending on curricula framework. Adult-child interactions oriented toward accomplishment of specific goals	Adult-led activities dominate.
Interaction	Emotionally present, supportive, responsive	Playfulness characterises adult-child interactions	For instructional purposes.
Output/ outcomes	Assumed this pedagogical style reveals needs, interests, dispositions and patterns of learning	Children's spontaneous activity is valuable for learning/ development. Structured play can promote specific outcomes.	Play is expected to promote specific ways of learning and lead to defined learning outcomes
Goals for pedagogy	Pedagogical decisions, curriculum planning, and provision of resources based on observation of children's activity	Curriculum goals are responsive to children. Framed as indicative goals to strive for rather than to achieve	Curriculum goals are central. Play activities are planned with adult, not children's goals in mind
Constraints	Curricula frameworks, space, time, adult, role, rules, parent expectations and schoolification	The more closely adult intentions are foregrounded the less likely the activity retains elements play/ playfulness	Play not valued for children's purposes. Complex benefits of play may be lost
Assessment	Narrative, holistic, emergent, and culturally responsive	Requires a dual focus. Assessment of goals adult has in mind when planning activity AND children's goals	Identify progress through developmental checklists and curriculum goals. Assess school readiness

Table 2.4 pedagogical styles common in EC (adapted from Wood, 2014; Hedges, 2022)

Wood (2014) argues that these contrasting pedagogical styles lead to unresolved tensions between policy and practice as all revolve around play, but elements of each conflict. When using Wood’s explanation, policy-driven play and child-initiated play have very little in common in how they might be understood, implemented, and resourced in EC settings. Adult guided play recognises the important role of the adult in supporting children’s learning (Wood, 2016) identifying a middle ground between formal teaching and free play. Those who oppose teaching or an emphasis on academic knowledge do not oppose creating learning opportunities for children, but concepts such as child-led, child-centred, child-initiated and discovery-learning have underpinned pedagogy in ECEC for decades. These traditions and the dominant discourse of finding teachable moments in free play run counter to the approach used when supporting STEM (Clements & Sarama, 2018, 2021; Langford, 2010; Lee & Ginsburg, 2009; Thiel, 2010; Thiel & Jenssen, 2018; Thiel & Perry, 2018). Adopting Wood’s conceptualisation of adult-guided play would enable educators to support the STEM process and discipline specific learning. However, intentional teaching or at least an intentional approach must be adopted. Despite large-scale studies demonstrating the need for a balance between child-led and teacher directed learning, intentional teaching is contested in ECEC (Grieshaber et al., 2021). It appears that difficulties in reconciling child-led learning through play and intentional teaching are most pronounced in the years just before school (Grieshaber et al., 2021). The need to examine the ways in which educators can move beyond laissez-faire approaches and facilitate academic learning by directing, collaborating, and extending a child's lead during play remain unresolved. This factor has implications for the implementation of STEM in EC contexts.

2.5.4 Conceptual Learning

In a similar vein, there are dilemmas pertaining to the learning and teaching of conceptual ideas in ECEC. STEM outcomes coveted by policy makers include process skills such as observing, describing, categorising, predicting, and communicating (Speldewinde & Campbell, 2023). But the development of conceptual knowledge and understanding related to the individual disciplines of science, technology, engineering, and mathematics, are also desirable. When considering the traditions, educational focus, and role of educator in EC as described in previous sections of this chapter, the idea of conceptual learning is contrary to this. EC educators who have strongly held beliefs about the importance of play and children's agency in ECEC, find it hard to accommodate the teaching of STEM content knowledge. The role of the adult in ECEC environments is that of facilitator and play partner and consequently, many EC educators are uncomfortable with the concept of *teaching* (Broström, 2017) which is perceived to be a requirement for STEM. Reconciling the nature of concept knowledge which requires adult support and direction to be achieved, and the notion of intrinsically motivated and imaginative play, is difficult. The idea that children's play is a natural form of healthy development that should not be subject to adult interference informs a long-held child-centred ideology linked to play (Hedges, 2014, 2022). For many, the introduction of conceptual learning, therefore, signals a change from one pedagogical approach to another, i.e. child-initiated to technicists (See **Table 2.4** for details) *and* a change to the role of the adult and centrality of play.

Exploring the role of children's content learning in play-based settings, Hedges (2014) outlines the tensions that exist between child-led and content-inclusive forms of pedagogy. She maintains that in European contexts, a long history of child-initiated, exploratory play ideology and the impact of developmental psychology are central to these issues. In EC, learning processes are deemed more important than curriculum content or outcomes, resulting in a focus on child development and pedagogical theories to the detriment of EC curriculum theory (Wood & Hedges, 2016). In child-led play, the adult is merely present to support children's normative developmental stages, as proposed by Jean Piaget (1896-1980). Hedges (2014) maintains that within this developmental sphere, the educator is not required to undertake active or intentional tasks, model the use of conceptual language or to mediate children's learning. Therefore, in the past there was no clear model for the adult to adopt when teaching concept knowledge as the role of the adult was considered superfluous to the child's normative and natural development.

This perspective began to change with the widespread acceptance of Vygotskian theories at the end of the 20th century. The work of Vygotsky (1978) was used to help formulate an approach that included a role for both the adult and the child in play and learning. According to Wood (2014) Vygotsky's Zone of Proximal Development [ZPD] (Vygotsky, 1978) was used to 'validate the play-pedagogy relationship on the grounds that young children benefit from adult scaffolding of imagination pretence and subject knowledge' (2014, p. 146). The Vygotskian approach provides an answer to the question of *how* to intentionally support concept development in a play-based environment, as it delivers practical steps and a theoretical framework that could respond to the dichotomy that exits between 'play' and 'teaching' (Bodrova, 2008).

As the intentional role of the adult is named in the Australian early years learning framework (Australian Government Department of Education [AGDE], 2022), much of the debate and academia in these areas comes from this part of the world. There is a growing recognition that some forms of knowledge require explicit teaching, but with the caveat that this should not disrupt or displace play (Fleer, 2010). It is possible for EC educators to use play-based pedagogy *and* intentionally teach specific STEM concepts (Thomas et al., 2011). Fleer's work on imaginary play (2019c, 2019a) builds on the work of Vygotsky and cultural-historical perspectives on play. Her conceptual PlayWorld and scientific PlayWorld models stress the importance of the adult in scaffolding children's engagement with scientific play and the importance of imaginative play in promoting scientific learning. This, and other approaches to conceptual STEM teaching, are outlined in the next section.

2.6 The Conceptualisation of STEM in EC Contexts.

The aforementioned factors of play tradition, child-centred practice in EC, the 'laissez-faire' role of the adult and a fear of schoolification pose challenges when attempting to find consensus about if/ how STEM should be included in EC curricula and practice. In several studies (for example, MacDonald, 2017; O'Neill, 2021; Park et al., 2017), educators agree with the introduction of EC STEM in theory, but often this agreement includes a caveat; a "yes, but…" answer. For example, educators report STEM skills are critical for children's futures, but fears around the appropriateness and impact of STEM content and approaches in ECEC persist (Alghamdi, 2022; O'Neill, 2021b; Wan et al., 2021). Simoncini and Lasen (2018) found that teachers see the value of EC STEM in preparation for later careers and education; for the development of dispositions and skills such as observing, inquiring, and experimenting; and the provision of exciting experiences. However, they also found that most EC educators (73%) prioritised children's social-emotional development and literacy learning above STEM education. In their meta-analysis, Wan et al. (2021) describe educators' responses to EC STEM as 'complex'. They found that educators accept the cognitive benefits and socially embedded rationales such future career prospects, but quickly list numerous challenges to its implementation. Practical challenges to STEM implementation are frequently cited and often include poor attitudes toward STEM, lack of confidence, inadequate content knowledge, limited resources, and time, perceived additional workload and poor professional development in relation to STEM (Jamil et al., 2018; Park et al., 2017; Stephenson et al., 2021; Uğraş & Genç, 2018; Voicu et al., 2022; Wan et al., 2021; Yıldırım, 2021). At first glance, these factors could be overcome through PD and by knowing more about how STEM and EC pedagogy is compatible. However, without a clear concept of what EC STEM is, how it is enacted in EC, and an understanding that it's introduction does not require specialist equipment, I fear these challenges will continue to be reported.

Play-based practice has been found to provide multiple rich experiences to support understandings of STEM (Bers et al., 2018; Campbell et al., 2018; Speldewinde & Campbell, 2023; Stephenson et al., 2021). Empirical study of four EC settings in Australia recorded instances of play demonstrating and fostering STEM conceptual knowledge *and* STEM process skills such as observing, describing, categorising, predicting, and communicating (Campbell et al., 2018). Findings concluded that adult-led activities arising from children's free play and ongoing interests were used to support integrated STEM experiences, particularly science and mathematics, but also found many examples of children's spontaneous play enabling discipline-specific and integrated STEM knowledge (Campbell et al., 2018). This point has been made elsewhere. A meta-analysis of EC STEM research concluded that perceptions of STEM in EC need to change. They suggest that the use of a STEM lens i.e. trying to see STEM in everyday activities and routines, would begin to extend understanding of EC STEM. They state 'There is a need to shift the lens and recognise everyday experience as opportunities to extend early learning about mathematical and scientific concepts such as learning about attributes and properties of materials' (Johnston et al., 2022, p. 13).

In addition, researchers have critiqued the use of STEM approaches adapted from other sectors or areas of education. It is argued that modifying models developed for older children in more structured environments can undermine ECEC's fundamental play philosophy, create challenges for provision and undermine educator confidence (Stephenson et al., 2021). Crucially any STEM pedagogical approach, PD or initial teacher education (ITE) needs to embed ideas in existing philosophy and curricula, building on the strengths of EC education rather than adapting one created for another educational context. Having a STEM model designed to reflect ECEC pedagogy can 'create the conditions for a positive shift in the motive orientations of early childhood teachers towards the possibility of re-engaging with the intentional teaching of STEM, while also increasing their confidence and competence' (Stephenson et al., 2021, p. 1). A handful of EC STEM models that inform how STEM education could be conceptualised exist, including makerspace approaches, conceptual play worlds and Katz's framing of intellectual rather than academic focus of EC STEM. Each is discussed in turn.

2.6.1 Conceptual Playworlds/ Science Playworlds

Fleer writes extensively about the educator's role in reconciling children's concept formation through play (Fleer, 2015, 2019c, 2019a, 2019a). Drawing on Vygotsky's cultural-historical theory (Vygotsky, 1987) she argues that development occurs through interaction with people and events and enables children to do more than they might do alone. Using this lens, children's cognitive learning is externally generated, making the mediating role of the adult crucial for learning (O'Neill, Gillic, & Kingston, 2022). Fleer suggests that educators should 'not be seen as passive providers of materials to foster developmental milestones, where the latter role… de-emphasises their place in children's learning' (Fleer, 2015, p. 41) and should reclaim their professional expertise as active agents in children's learning. Without utilising didactic methods intentional teaching enables children to make transition to new and more complex forms of learning (Wood & Chesworth, 2017). This is a way to amplify development, enrich and expand the content of play, rather than a forced acceleration one might expect in school readiness (O'Neill, Gillic, & Kingston, 2022).

A STEM practice model for play-based settings that can progress pedagogical practice and teaching to engage young children and support the development of essential STEM skills (Fleer, 2019c). The conceptual PlayWorld model is proposed to bring together play learning and development as an approach that can blend guided play while allowing children to have their own agency and motivation in an attempt (Fleer, 2019d). The objective of conceptual PlayWorlds is to meaningfully support children's learning of concepts and build executive function in play-based settings where 'learning is in the service of the children's play' (Fleer, 2019a, p. 3). Adapted from the original PlayWorld model (Lindqvist, 1995), this method provides a pedagogical framework to support and extend conceptual development through imagination and playfulness, encouraging educators to use their play expertise and storytelling abilities to conceive of imaginary situations with children (Fleer, 2019c, 2019a; Stephenson et al., 2021). According to Fleer (2019a) conceptual PlayWorlds enable EC educators to enhance children's STEM concept development by creating imaginary situations, typically inspired by story books, to learn STEM concepts and encounter and solve STEM-related challenges**. Table 2.5** outlines key steps in designing a conceptual PlayWorld.

1. Selecting a story.	Select a familiar story upon which the imaginary situation will be based. Within the PlayWorld, educator and children take on the role of characters from the story and use the narrative to create a problem situation that needs STEM-related concepts to be solved.
2. Designing a space.	Design a space that will be used for the PlayWorld. For example, the block corner or outdoor space can be transformed into a PlayWorld
3. Entering and exiting the PlayWorld	Plan how to enter and exit the PlayWorld as a group. For example, signal a move into the PlayWorld by putting on special hats, or stepping over a barrier
4. Planning the problem scenario	A problem that needs to be solved is identified within the drama of the story. For example, a letter may arrive from one of the story characters, asking for help
5. Planning the role of the teacher.	Finally, educators must consider their role in the drama and their interactions with the children.

Table 2.5. Steps in designing a conceptual PlayWorld. Adapted from Stephenson et al., 2021

This model creates a clear role for the adult and provides a framework to support STEM process and conceptual learning in EC settings. What's more, this is a well-researched model based on multiple empirical studies including those focusing on supporting girls to embrace STEM in EC.

2.6.2 Makerspaces

'Contemporary literature reinforces the need for settings that support STEM thinking and learning…While makerspaces are an emerging area of focus in early childhood spaces, clear alignments can be seen for opportunities to support STEM and STEAM learning' (Johnston et al., 2022, p. 3)

Definitions of STEM require essential elements (integration of discipline areas, real-world problems, the development of meta-skills and so on), which in theory at least, can all be achieved through the provision of Makerspaces. Makerspaces prescribe learner-centred pedagogies where participants work across a range of STEM areas on creative design projects (Dougherty, 2013; Kumpulainen & Kajamaa, 2020; Woods & Baroutsis, 2020) and have carefully curated conditions. Learning across disciplines, engaging with design, iterative processes, the development of new skills and having fun are central to aims of Makerspaces (Wyld & Dierking, 2015). Interest from the education sector has emerged due to the collaborative design, making activities, and promise of supporting STEM understanding. As well as providing novel materials (new and traditional technology), the pedagogical approach differs from more formal education as educators are positioned as collaborators, empowering children to lead experiences (Johnston et al., 2022; Marsh et al., 2017; Woods & Baroutsis, 2020). Makerspaces have been shown to support the development of transversal competencies, such as innovative thinking, creative problem-solving and interpersonal skills collaboration (Blum-Ross et al., 2020; Kumpulainen & Kajamaa, 2020; Sheridan et al., 2014) which can meet the demands of policymakers and support children to explore and use their interests as starting points for learning. In addition, Makerspaces support children's agency and self-belief, link the practice of making to formal concepts and theory and be tailored to a variety of contexts and diverse learners (Dougherty, 2013).

The Maker Movement has developed in out-of-school spaces and has mostly involved adult participants (Peppler et al., 2016) but was quickly adapted for use with families and young children in libraries and museums (Honey & Kanter, 2013; Sheridan et al., 2014). The potential benefits for ECEC, especially as a pedagogical approach have begun to be recognised (Marsh et al., 2019) and growing interest among early years educators to use makerspaces to enhance opportunities for children to engage in design and engineering experiences is evident in literature (Bresson & King, 2017; King, 2017). Like typical ECEC environments, play is recognised as an important factor in the provision of Makerspace environments that promote engagement, creativity, and social participation (Marsh et al., 2019). Makerspaces provide opportunities for children to explore personal interest and develop skills and knowledge individually *and* provide numerous opportunities for children to draw on their funds of knowledge in their learning with each other (Marsh et al., 2019). They are, therefore, reflective of children's backgrounds and support their agency.

European projects such as MakeyEU have provided opportunities to test makerspaces in EC and other community spaces across a variety of countries and in several ways with positive results. Much like EC, Makerspace research is largely addressed through constructivist frameworks that assume interaction is the basis for learning, which has identified benefits such as collaboration, creativity and scaffolding (Sheridan et al., 2020). Makerspaces in ECEC have been shown to positively impacted children's thinking and metacognition is (Hatzigianni et al., 2020) and support the development of knowledge and process skills needed as the world becomes ever-more technologized (Marsh et al., 2019).

Doherty (2013) posits that Makerspaces can be tailored to a variety of formal and informal contexts and diverse learners, cultivate relationships that link the practice of making to formal concepts and theory; to support discovery and exploration while introducing new tools for advanced design and new ways of thinking about making; develop in all students the full capacity, creativity, and confidence to become agents of change in their personal lives and in their community. In this way, it has been argued that makerspaces provide opportunities for those normally excluded from STEM (Keune et al., 2019; Peppler et al., 2016; Peppler & Bender, 2013), responding to the needs of children from minority backgrounds. As such, this model could include a wider variety of children and communities and support STEM learning and future prospects without using didactic teaching approaches.

2.6.3 Intellectual Goals rather than Academic Outcomes

Finally, reframing EC STEM as something that supports children's intellectual pursuits rather than enforcing formal learning outcomes may encourage EC educators to see the potential of STEM. When considering EC STEM education, Katz (2010) makes a useful distinction between academic and intellectual goals and delineates between these conflicting foci. Rather than situating EC STEM as part of the school readiness agenda, she proposes an alternative conceptualisation. Arguing that framing EC STEM as a way to prepare children for school or later life is misleading and can lead to the design of unsuitable and ineffective provision. Instead, Katz (2010) proposes that STEM processes are a tool that can support children's thinking and metacognitive skills in partnership with a skilled adult and can maintain the child-centred approach common in EC. See **Table 2.6** for details.According to Katz's ideology, the processes of seeking, exploring, and developing knowledge is paramount, and EC STEM experiences should strengthen children's intellectual dispositions and lead to a better, fuller, and deeper understanding of their world. This is illustrated by:

- "Being engaged in extended interactions (e.g., conversations, discussions, exchanges of views, arguments, participation in planning of work).

involved in sustained investigations of aspects of their own environment and experiences worthy of their interest, knowledge, and understanding.

- Taking initiative in a range of activities and accepting responsibility for what is accomplished.
- Experiencing the satisfaction that can come from overcoming obstacles and setbacks and solving problems.
- Having confidence in their own intellectual powers and their own questions.
- Helping others to find out things and to understand them better.
- Making suggestions to others and expressing appreciation of others' efforts and accomplishments.
- Applying their developing basic literacy and numeracy skills in purposeful ways" (L. Katz, 2010, p. 5).

Academic Goals	**Intellectual Goals**
Children acquire discrete pieces of information and facts, often disconnected from context.	Emphasises reasoning, hypothesising, predicting, conjecture and the quest for understanding
Focus on academic competencies – reading, writing and ability to provide 'correct' answers when quizzed.	Focus on personal dispositions that allow them to make sense of their experiences and environment
Support later literacy, numeracy, or other academic learning	Encourages children to seek mastery of academic *skills in service of their intellectual pursuits*
There are correct answers that must be memorized.	The search for understanding takes many forms
Learning 'of little practical value'	Children appreciate the usefulness and various purposes of their endeavours.

Table 2.6. Comparison of Academic and Intellectual Goals (adapted from Katz, 2010)

This approach could be adopted into EC environments without challenging the beliefs and self-efficacy of educators. In addition, Katz is a supporter of emergent and enquiry-based approaches (see Katz & Chard, 2000) which is endorsed in the current Irish EC Curriculum framework (NCCA, 2009).

2.7 Educators' STEM beliefs, Attitudes, and Knowledge

Educators' beliefs and confidence affect their behaviour, practice and, consequently, children's learning (DeCoito & Myszkal, 2018; Kelly et al., 2022; Nikolopoulou & Gialamas, 2015a, 2015b). Beliefs and attitudes in relation to STEM are complex and research findings suggest that attitudes are multifaceted and at times, contradictory (MacDonald, 2017; O'Neill, 2021a). Factors that impact practice can be internal, for example beliefs, attitudes, and views; or external, for example access to resources and training (Palaiologou, 2016). Despite current interest and focus on STEM education, these factors continue to impact the extent to which educators effectively enact STEM in their settings. A number of these factors will be discussed further below, including the role of the adult, knowledge requirements related to EC STEM and the impact of STEM self-efficacy.

2.7.1 Pedagogical Content Knowledge (PCK) in the Republic of Ireland

The role of the adult has been identified as crucial in introducing and sustaining children's interest in, and understanding of, STEM disciplines (Department of Education and Skills, 2020b; Donohue, 2019; Early Childhood STEM Working Group, 2017; Gerde et al., 2018; Moore et al., 2014; Waite-Stupiansky & Cohen, 2020). EC educators' STEM knowledge is often cited as a stumbling block in relation to EC STEM implementation (Stephenson et al., 2021). Shulman (1987) identified multiple dimensions of teaching knowledge including content knowledge (CK), pedagogical content knowledge (PCK) and later, general content knowledge (GCK). These core areas of knowledge inform an educator's teaching. CK refers to knowledge of the subject, for example shape, number sense or data analysis in mathematics. PCK relates to knowledge about teaching and learning a specific subject, for example the engineering design process or scientific process. GPK pertains to knowledge not specific to any particular subject, for example the use of authentic investigations, play or real-world application of problems. Ulferts (2019) maintains that general pedagogical knowledge is what educators draw on in order to design beneficial learning environments in their settings, and for high-quality teaching. Having reviewed a number of empirical papers Leijen et al (2022) identified a number of GCK characteristics including those that relate to children, for example knowledge of child development or learning processes; those related to teaching, for example classroom management and organisation, teaching methods or assessment; and context characteristics, for example, curriculum, philosophy of education. It could be argued that EC educators are generalists and that their GPK is already excellent - practice is child-led, hands-on and tends to emerge from children's interests. These are areas where *Irish* EC educators have participated in considerable PD in the past decade. PD related to Aistear, the National Early Childhood Curriculum Framework (National Council for Curriculum and Assessment, 2009), Síolta, the early childhood quality framework ((Department of Education and Skills, 2017a) and their online companion Practice Guide has led to significant PD opportunities in the areas of curriculum foundations, play, interactions, working with parents, learning environment, transitions, and emergent and inquiry-based learning.

In contrast, content knowledge is lacking in early childhood in ROI where a more holistic approach to teaching and learning dominates. Little time is given to content knowledge in initial teacher education or PD, and educators report not feeling confident in their STEM knowledge or skills (Department of Education and Skills, 2020c; O'Neill, Gillic, & Winget-Power, 2022; O'Neill, Gillic, et al., 2023). Multiple international research studies indicate that EC educators do not acquire sufficient STEM content knowledge in initial education, leading to poor self-efficacy and issues implementing STEM in their settings (Chan et al., 2023; Park et al., 2017; Yıldırım, 2021).

STEM content knowledge is extensive. Considering one discipline, Clements and Sarama (2021) identify twenty maths learning trajectories, divided further into sub trajectories. Each learning trajectory needs to be understood in terms of their three component parts 'A mathematical goal, a developmental path along which children develop to reach that goal, and a set of instructional activities, or tasks, matched to each of the levels of thinking in that path that help children develop ever higher levels of thinking' (Clements & Sarama, 2021, p. 4). Thus, educators need to understand CK related to each of these trajectories and the PCK to be able to identify and support them in EC settings. Similarly, the Erikson early maths collaborative identify nine maths content areas or 26 'big ideas' that children need to grapple with between 3-6 years (Early Math Collaborative, 2014) and for children younger than 3 years there are 4 precursor concepts, composed of 12 sub-concepts (Hynes-Berry et al., 2021). I teach an early maths undergraduate module which attempts to cover this CK in a single semester. It is a struggle to cover CK and PCK of early mathematics, let alone content for other STEM disciplines.

The lack of EC STEM CK and PCK is problematic for several reasons. Firstly, emerging EC STEM policy recommendations often presuppose that the workforce is knowledgeable about curriculum, pedagogic interactions, language, early literacy, and executive functioning skills (Rogers et al., 2020a). Policy is introduced under 'an assumption that educators have the necessary content knowledge across STEM domains of science, technology, mathematics, and engineering. However, this is often not the case' (Johnston et al., 2022, p. 1). Secondly, these recommendations place untenable demands on educators to gain this knowledge, and on teacher educators to meet the requirements to teach within and across

STEM disciplines (Barkatsas et al., 2018; Fraser et al., 2018). Siskind et al., (2022) question whether teacher educators possess the comprehensive knowledge, pedagogical skills and understanding of the challenges and benefits of STEM. Certainly, in ROI, teachers and educators report that they would welcome more support and guidance on how to teach and what to teach about STEM (O'Neill, Gillic, O'Reilly, et al., 2024). Thus, it is imperative to examine competence at multiple levels within the EC environment.

Thirdly, DeCoito and Myszkal (2018) argue that STEM CK also includes the understanding of the importance of facilitating STEM identity, fostering student STEM identity development from a young age and broader understanding of what it means to engage in a STEM career. The ability to set up environments that cultivate realistic problem-solving situations, devise scenarios that require a group inquiry approach and facilitate discussion about the key problem and potential solutions require a whole extra set of skills (Fraser et al., 2018). This requires substantial modifications in pedagogy, curriculum, and assessment, all of which can be perceived by educators as a barrier to implementation (Margot & Kettler, 2019).

Finally, the extent of knowledge that is required to successfully enact STEM approaches is vast. When considering *how* to support EC educators' understanding and implementation of STEM in their classrooms confidently and effectively, Wan et al (2021) outline three levels of STEM integration that have clear implications for PD and ITE. Firstly, discipline content knowledge needs to be improved. STEM definitions require that at least two disciplines be integrated and applied. Research suggests that early childhood educators have limited content knowledge in math (Chen et al., 2014), science (Gerde et al., 2018; Ravanis, 2022), engineering and technology. To support STEM, a proficiency in the fundamentals of each discipline is the first step toward competent EC STEM education. This gap in knowledge needs to be addressed and self-efficacy enhanced before moving on to the second level of PD; discipline integration. Finally, Wan et al (2021) outline innovation- driven integration as the most complex form of PD but the pinnacle or goal of such education. This refers to creative problem-solving using knowledge from across discipline areas to come up with ideas and apply solutions to any given problem posed in an EC classroom. As Wan et al. comment 'This is the underlying reason for emphasizing integration in STEM education' (2021, p. 957). It is assumed that once educators are more aware of these three levels of STEM integration they will:

> 'have a clearer understanding of the concept of STEM, with which they can relate STEM education with what is being done by them, have greater intentions to incorporate additional STEM elements in their existing curriculum, and realizing the meanings of implementing STEM education through establishing the linkage between EC STEM education and the learning at subsequent school and university stages.' (Wan et al., 2021, p. 958)

The term self-efficacy refers to an individual's belief in their capacity to perform in the ways necessary to reach a specific goal (Bandura, 1977, 1997). Internationally, EC educators' report a lack of confidence and poor self-efficacy in mathematics (Anders & Rossbach, 2015; Chen et al., 2014; Gerde et al., 2018), science (Fleer, 2009; Gerde et al., 2018; Ravanis, 2022), technology (Dardanou & Kofoed, 2019; Fotakopoulou et al., 2020; O'Neill, 2021b; Worch et al., 2012) and engineering (Lippard et al., 2017, 2019). Wan et al. 2021 argue that teachers' hesitation to implement STEM in their settings is down to two reasons, 1) a lack of understanding about the integrated nature of STEM and 2) the apparent complexity of STEM teaching. PD can be transformative in changing attitudes and self-efficacy around

STEM (DeCoito & Myszkal, 2018; Stephenson et al., 2021). STEM self-efficacy is positively correlated with STEM teaching experience, possessing an interest in STEM, or having participated in STEM-related activities (Chen et al., 2021). Thus, ITE and PD should provide courses through which educators can develop STEM practical teaching experiences.

2.7.2 Professional Development for EC STEM

To keep pace with new research, growing societal expectations, increasing standards, accountability and governance, educators are expected to continuously engage with PD to maintain and improve quality of practice (OECD, 2005; UNESCO, 2020). However, the amount of time spent preparing educators to support EC STEM is still low (Brenneman et al., 2009; Lange et al., 2021; S. Ryan et al., 2014). There is a need to clarify educators' role when supporting STEM (Fridberg & Redfors, 2024) and for improved preparation for educators to understand STEM discipline content and provide experiences integrating this content into their pedagogy (Brenneman et al., 2009).

Research continues to find that EC educators have a lack of knowledge and experience in STEM education, limited content knowledge and difficulty integrating the knowledge and skills of different disciplines (Çiftçi et al., 2022). STEM subjects are typically not included in ECEC initial education in ROI and are not a requirement at any ECEC qualification level. Unsurprisingly then, 50% ECEC educators in ROI report that their training has not prepared them to teach mathematics in ECEC (Department of Education and Skills [DES], 2016) and 75% of educators are unsure how to include technology in their classrooms 'in a way that was appropriate to the age of their learners' (Department of Education and Skills, 2020c, p. 26).

There is still some question about how effective EC STEM PD is in changing practice. Much of the current research in EC STEM chronicles changes in beliefs, attitudes, or self-efficacy (Wan et al, 2021). A change in thinking doesn't necessarily lead to change in practice as much as a change in cognition doesn't automatically lead to a change in behaviour (Hoekstra et al., 2009; Korthagen, 2017). STEM PD often necessitates considerable shifts in pedagogy, curriculum, and assessment, all of which can be perceived by educators as a barrier to implementation (Margot & Kettler, 2019). For example, in her study DeJarnette (2018) reported that educators acknowledge the support and resources provided and report more positive belief about STEM. However, she found that some were still reluctant to adopt STEM approaches stating they would like to spend more time to getting comfortable with content before introducing it in their class (DeJarnette, 2018). Ideas about STEM may change but self-efficacy may not. A recent scoping review (MacDonald et al., 2024) found that the majority of the 22 professional development opportunities being offered were structured as workshops or in-service training. And while positive outcomes from the participants' engagement with early childhood STEM professional learning were reported, a number of the papers reviewed argued that the evidence base for early childhood STEM professional learning needs to be expanded considerably (MacDonald et al., 2024).

Lack of EC STEM application could be due to several factors. The context in which educators find themselves has the potential to motivate or deter educators from attending PD. Personal characteristics, beliefs, and self-efficacy as well as workplace relationships and conditions can influence educators' motivation for learning (Zhang et al., 2022). The ongoing issues with poor pay and conditions in ECEC may also impact educators' absorptive capacity or their ‘ability to acquire external resources and knowledge, and then assimilate and apply these’(Øian et al., 2022, p. 26). Authentic STEM necessitates the use of new pedagogies and ideas which can be challenging for the educator. In STEM professional development, a focus on self-efficacy, pedagogical beliefs, *sustained* supports are warranted as these are the factors influence their motivation, behaviour, and pedagogical strategies (Chen et al., 2021; DeCoito & Myszkal, 2018).

The challenge of supporting STEM understanding is cited frequently in research (for example, Alghamdi, 2022; Park et al., 2017; Ring et al., 2017; Rogers et al., 2020a, 2020b; Sheridan et al., 2009). Most STEM PD for educators is short, patchy, ineffective, and does not take into consideration the educator’s specific needs (S. Wilson, 2011). Brief, one-off PD does little to challenge beliefs about STEM, build confidence, develop understanding, or build educator’s capacity to engage in STEM pedagogies (Fraser et al., 2018). An intellectual understanding of STEM theory can often be the focus of PD, without an emphasis on enactment in practice or a focus on influencing educators’ underlying beliefs or attitudes toward STEM education. Short term training (between 1 hour and 1 day) is insufficient to transfer STEM content knowledge and impact confidence enough to have a change in EC settings (Wan et al., 2021). Further evidence about duration, frequency, and intensity of PD, though likely to be important factors in the degree of effectiveness, is inconclusive and requires further research (Rogers et al., 2020a).

In their study, Ring et al., (2017) worked with educators from EC to post-primary on a 3-week long intensive STEM PD project. The authors documented educators’ conceptions of integrated STEM and how these changed over the course of the project. They argue that fundamental concepts (i.e. how STEM is conceptualised and defined) need to be understood before attempting to implement STEM as ‘as one must come to terms with one’s understanding before attempting to enact integrated STEM education’ (Ring et al., 2017, p. 463). More importantly, their findings suggest that those facilitating STEM PD recognise that educators present with preconceived ideas about STEM. Therefore, participants' various understandings should be acknowledged, and educators allowed time to reflect on their own conceptions, individually and with others. Otherwise, they argue, the goals of the PD may conflict with educators’ beliefs and understandings and the learning goals will not be met (Ring et al., 2017).

Further, the varied professional profiles of the ECEC sector in Ireland suggest the need for different types of intervention and professional development to reflect the needs of individuals (O’Neill, Gillic, & Winget-Power, 2022) and to meet the needs of such a disparate cohort, a variety of PD approaches and sustained supports in various guises are required. A recent Irish study found that educators preferences about STEM PD varied considerably (O’Neill et al., 2023). Some preferred site visits to settings where STEM practice was deemed of a high standard, communities of practice, and others wanted experts to visit their setting to support the entire team. Further, existing support structures were positively reviewed, and educators recommended using these organisations to facilitate PD (O’Neill et al., 2023).

Pacini-Ketchabaw et al (2022) describe the need for a wide variety of learning modes to be catered for in STEM PD, use of multidimensional approaches and the importance of challenging educators to interrogate their beliefs. PD is most effective when it involves a chance to integrate new knowledge and understanding into day-to-day practice, and to reflect on this over time. Generic, didactic methods often fail to produce the transfer of skills to the setting or a meaningful change in pedagogy (Sheridan et al., 2009). This is in line with advice for adult learners as sustained and tailored PD can impact cognitive, motivational, and emotional dimensions of learning, and is therefore more effective at influencing educators' behaviour (Korthagen, 2017). Specialist coaching, mentoring and peer-to-peer reflection are flexible PD models that offer the responsive approach required where a diverse workforce has a wide variation in skills, knowledge, and qualifications (Rogers et al., 2020a). Stephenson et al (2021) found that PD with follow up support on site led to a positive shift in the motive orientations of early childhood teachers and increased both competence and confidence with the intentional teaching of STEM. Elsewhere, communities of practice have been found to support ECEC educators' understanding of STEM (Boonstra et al., 2023).

Policy solutions are often streamlined and designed for a quick-fix solution (Fullan, 2016). Policy makers must be made aware of the need for increased time for educators to work together to create innovative ways to successfully integrate STEM education in their settings and identify their ongoing training needs (Margot & Kettler, 2019). The intention of providing long-term support in multiple formats to support EC STEM may challenge current practice and PD structures. This view of PD is a change to the status quo and requires quite a shift in perspective, especially for many policymakers. Simmie (2023) argues that enforcing educators' learning in particular areas is limiting when it is framed as a linear process that does not consider the 'many unsolvable dilemmas and contradictions' of practice. As Fullan (2006) notes in his overview of what is known about teacher change, 'the use of change knowledge does not represent a quick fix, which is what many politicians seek' (p. 13). To be successful, PD needs to shift away from a pre-planned curriculum and be responsive to individuals, their settings, and circumstances (Korthagen, 2017; Korthagen et al., 2006). Acknowledging the neo-liberal ideas that shape EC through supranational and national policy (Wood & Hedges, 2016), the very idea of standardised continuing professional development for educators should be interrogated.

2.8 Developing STEM Identity

STEM identity is described as the extent to which a person sees themselves as a member of a STEM field, and views themselves in terms of the behaviours, values, attitude, traits, and norms inherent in those fields (Hachey, 2020). The development of STEM identity i.e. seeing oneself as a STEM person, at an early age is a perceived benefit of EC STEM education (Dou et al., 2019; Hachey, 2020; Hachey et al., 2022; Maltese et al., 2014; Maltese & Tai, 2010) while the neglect of STEM identity development in children's earliest years results in a declining interest in STEM for girls and minorities that can impact later participation in STEM-related fields (Hachey, 2020; Hachey et al., 2022; Wladis et al., 2015).

Examining the relationship between early childhood STEM experiences and STEM identity, early informal experiences, such as tinkering with electronics, have a positive impact in STEM attitudes and STEM identity (Dou et al., 2019; Johnston et al., 2022). Attitudes toward STEM form early on, and persist into teenage years and beyond (Clerkin & Gilligan, 2018; Gilligan et al., 2023; Morgan et al., 2016). ECEC environments can either provide or prevent access to meaningful STEM experiences, that in turn foster young children's early self-understandings and ways of positioning themselves in relation to STEM (Hachey et al., 2022). The absence of STEM from ECEC implies that it is unimportant or unsuitable for children. It suppresses STEM-related play, exploration, and role-taking, and provides an implicit message that STEM, or its constituent parts are irrelevant (Hachey, 2013). This 'denies young children the opportunity to form a deep affiliation with STEM content and practices that stimulates the habits of mind that are critical to STEM identity development, and that prepares children for later competencies in STEM disciplines' (Hachey, 2013, p. 137).

2.8.1 Influence of Gender

Gender equity is a topic frequently cited in relation to STEM literature (for example, (Areljung & Günther-Hanssen, 2022; Buck et al., 2020; Gilligan et al., 2023; Hallström et al., 2015; Lyttleton-Smith, 2019; Niepel et al., 2019; Wladis et al., 2015) and outlines that women are significantly less likely to select STEM further education courses and pursue STEM careers (Keune et al., 2019). This is considered problematic as wider and more varied perspectives are thought to lead to better STEM solutions and STEM careers are highly paid, contributing to equality of income across the sexes (Change the Equation, 2022). As such, policy initiatives often contain reference to this imbalance, and policy implementation is identified to counter this (Cunningham & Villaseñor, 2016; European Commission, 2023; Eurostat, 2019; Munoz Boudet et al., 2021; OECD, 2017, 2021b; Subasinghe et al., 2023; World Bank, 2017).

EU policy promotes gender balance in STEM disciplines to support economic growth *and* equality (European Commission, 2023; European Parliament, 2021). Similarly, the UN's Sustainable Development Goal (SDG) number 4 aims to 'Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all' (UN, 2015, p. 17). Targets outlined aim to increase the number of individuals with appropriate STEM skills (target 4.4) and eliminate gender disparities in education (target 4.5). In the Republic of Ireland, the DOE have identified gender imbalance as a challenge in the STEM Education Policy Statement (Department of Education and Skills (DES), 2017b) and published a number of documents aimed at addressing the gender gap in STEM learning, STEM subject selection in post primary education, STEM third level education and eventual STEM careers (Department of Education, 2023b; Department of Education and Skills, 2022; Department of Education and Skills (DES), 2017a; Department of Education and Skills, 2020c).

This gender disparity cannot be attributed to girls' lesser capabilities. Research shows that girls' STEM abilities are equal to, or better than their male counterparts (Niepel et al., 2019; O'Dea et al., 2018; Wang & Degol, 2017). This competence does not translate to equal numbers of men and women pursuing STEM qualification or careers, as one might expect. Investigating the timing, source, and nature of graduates' earliest interest in STEM, over two-thirds (65%) of respondents report that their interest began before eleven years of age (Maltese & Tai, 2010). Further, female science graduates were more likely to report that their interest in science was sparked by school-related activities, while their male counterparts cited self-initiated activities as the origin of their curiosity. This study highlights the importance of exposure to out-of-school STEM activities *and* the importance of more structured activities for young girls to establish and maintain a STEM identity. This is of importance as girls in EC have been shown to be marginalised from STEM and are likely to be influenced by education-based STEM activities where early introduction can counter issues with gender-based perceptions of STEM (Fleer, 2021; Maltese & Tai, 2010; Sullivan & Bers, 2013).

Increasingly, research suggests that girls' understandings of STEM are also influenced by their identity alignment with these disciplines (Campbell et al., 2020). When investigating how bush-kinders, comparable to forest school approach found in Europe, support STEM, one study found that nature-based play scenarios supported girls' STEM learning and development of a STEM identity (Speldewinde & Campbell, 2023). Further, it was argued that the development of girl's STEM identity hinges on the provision of a positive STEM learning environment, *and* social interaction with significant adults to support interest act as enablers of STEM learning (Speldewinde & Campbell, 2023). Which leads to a further point about the complex relationship between gender and STEM. A recent literature review in ROI acknowledged the multiple factors that influence gender imbalance in STEM, starting in ECEC (Department of Education and Skills, 2020a). A child's identity is 'socially constructed, performative, complex, relates to context and can vary depending on circumstance' (Speldewinde & Campbell, 2023, p. 272). Investigating issues through multiple lenses highlights how the learners themselves, their families, educators, and society, affect girl's perceptions of STEM and STEM identity.

1. **Learners.** Literature reports that girls are unable to access STEM resources and STEM spaces [such as block area] in ECEC settings, and where they can access these spaces, they are often quickly pushed out by boys' more boisterous play style (Bagiati & Evangelou, 2015; Buck et al., 2020; Fleer, 2021; Lyttleton-Smith, 2019). If we concede that STEM identity begins in early childhood, this lack of access sends a strong message to girls about who 'does' STEM and can hinder developing conceptions of STEM identity and future involvement in STEM.
2. **Family.** Family can unintentionally contribute to gendered ideas about STEM, reinforced through their discussions and interactions with children. For example, in naturally occurring family conversation parents are three times more likely to explain science to boys than girls (Crowley et al., 2001). Parents' encouragement of science interest varies by child gender and these behaviours are related to children's science achievement beliefs, i.e., ability perceptions (Bhanot & Jovanovic, 2009). A

recent Irish study found that over half of parents express a lack of confidence in talking about or doing science with their young children and mothers reported even less confidence in doing science activities with their children (Gilligan et al., 2020).

3. **Educators**. Decades of research illustrate the lack of EC teacher preparation in and comfort with STEM disciplines (Hapgood et al., 2020; Waite-Stupiansky & Cohen, 2020; Wan et al., 2021) let alone emerging gender issues. Initial education and PD should address how educators can create equal opportunities for boys and girls in free play as educators do not actively provide boys and girls equal opportunities to explore and use material and toys which are not gender stereotyped (Hallström et al., 2015). Fleer (2021) surmises that unless practice traditions in ECEC are disrupted, girls will continue to be marginalised from essential STEM knowledge.
4. **Society.** A lack of societal STEM gender diversity, i.e. not seeing themselves represented in children's literature, media or wider society negatively affects students' positive STEM self-concept formation (Department of Education and Skills, 2020a; Niepel et al., 2019). Societal and systemic issues often mean that gender is often combined with other social identity characteristics such as race, class, sexuality, and ability to produce experiences of further marginalization (Belkhir & Barnett, 2001; Smooth, 2013). Girls from high-poverty areas are least likely to have access to STEM classes, resources and experiences (Alexandre et al., 2022; Change the Equation, 2022). They are also less likely to be offered the high-level STEM courses in post-primary education that are required to access third-level STEM programmes (Jong et al., 2020). This intersectionality compounds issues experienced by girls in relation to STEM

The literature outlined here provides bleak reading and leads to a greater understanding of how and why girls are excluded from STEM long-term and/or make choices other than STEM in their education and careers. Positively, the literature also shows that EC is influential in establishing and embedding girl's STEM identity (Areljung & Günther-Hanssen, 2022; Buck et al., 2020; Charles & Thébaud, 2018; Fleer, 2021; Hallström et al., 2015; Lyttleton-Smith, 2019). What's more, it is possible to transform EC environments and empower girls to access STEM spaces traditionally difficult for them to enter, by disrupting gendered interactions and play (Fleer, 2021). The role of the educator is central to this goal, as they provide safe spaces for girls to explore STEM. Interactions with supportive educators affirms girls' place pertaining to play-based STEM experiences (Fleer, 2021; Speldewinde & Campbell, 2023). Fleer explains that positive outcomes were evident as 'girls were given time, space, resources; were listened to; positioned positively to make contributions; and were given a voice to lead/share/theorise/predict/ showcase their ideas' (2021, p. 14).

2.9 Conclusion

This chapter has outlined key literature and concepts related to EC STEM. Debates relating to the conceptualisation of EC, suitability of EC STEM, purposes and aims of STEM in EC and the role of the EC educator prove to be complex. To better understand the implications for the research question 'how should STEM education be implemented in ECEC in ROI?' The next chapter will focus specifically on EC and EC STEM policy in ROI.

Chapter 3 - Early Childhood Education in the Republic of Ireland

Chapter 3; Early Childhood Education in Ireland, A Policy Overview

3.1 Introduction

The focus of this study is on the implementation of EC STEM in the Republic of Ireland. As early childhood education can only ever be understood in the wider context of the society that surrounds it (Hayes & Urban, 2018a; Hayes & Walsh, 2022) this chapter endeavours to provide an overview of that context. Large-scale investment and a series of major policy reforms since the early 1990s has seen the Irish ECEC system go through enormous change (see Hayes & Walsh, 2022 for a comprehensive overview). The introduction of an early years curriculum framework (2001), free state-funded preschool services (2010), an early years strategy (announced 2013), an access and inclusion model for children with additional needs (2013), an education-focused inspection regime (2015), minimum qualification criteria for educators (2015) and the appointment of a Minister for Children (2011) have been welcomed by the sector. Despite these changes, the Irish ECEC policy system has not 'transformed' and the State maintains a hands-off approach (Wolfe et al., 2013).

3.2 Structure of EC Education

In the absence of a national philosophy or policy about early childhood education within the State, ECEC settings developed in an ad hoc manner (Hayes, 1995). By the early 1990s, and with the support of EU funding, major government ECEC initiatives were introduced concentrating on issues of accessibility and affordability for parents. In the years since, focus has shifted to governance, inspection, and state funding schemes (OECD, 2021c). The relationship between the ECEC workforce, their working conditions, EC educator qualifications, initial education and the quality of provision has been largely overlooked (Hayes, 2010; Moloney, 2021; Murphy, 2015; OECD, 2021c, 2021b). Yet, EC educators face increasing accountability and layers of governance within a highly complex policy and practice landscape (Moloney, 2021; Murphy, 2015) with policy and financial arrangements that are unduly burdensome (OECD, 2021c).

ECEC in Ireland is a historically fragmented sector (Moloney, 2021; Moloney & Pope, 2015; Murphy, 2015), lacking a single representative body for the workforce, or a single government department responsible for ECEC as a whole. **Figure 3.1** provides an overview of current governance structures and a list of other government departments with a stake in ECEC affairs.

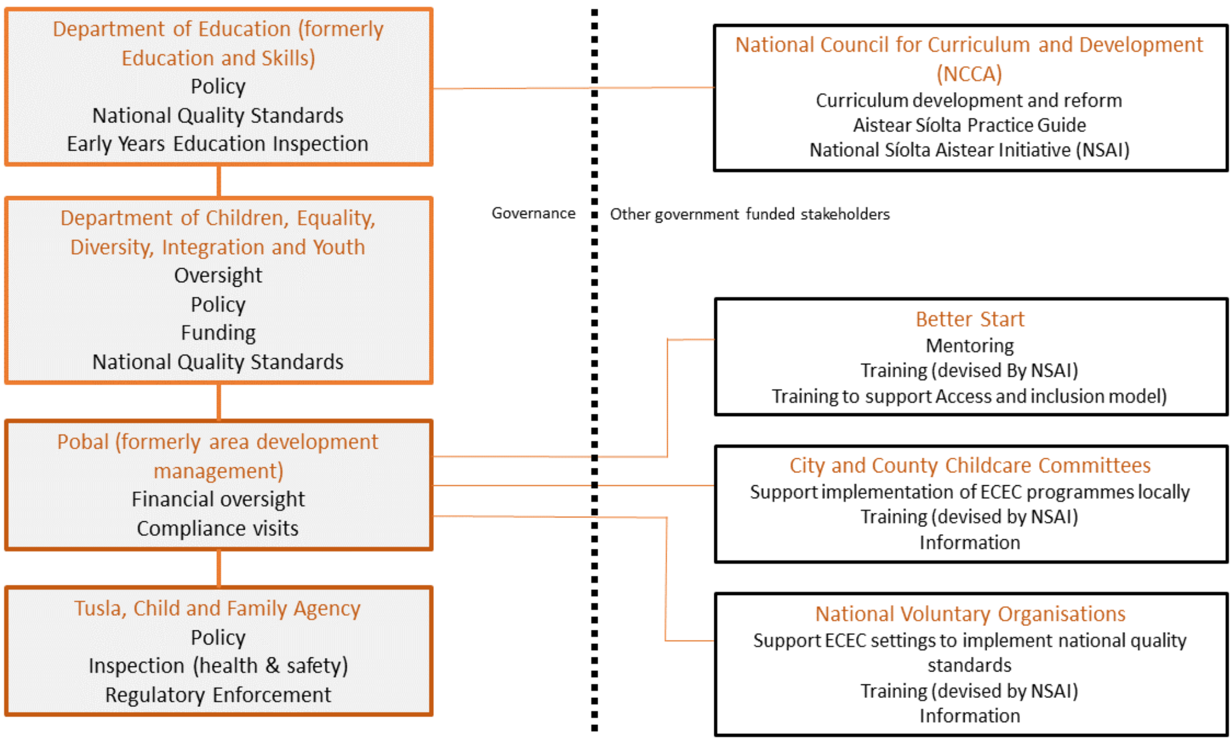

Figure 3.1 -Overview of macro-level governance of ECEC sector.

Figure 3.1 illustrates the divested responsibility for early childhood, and the multiple organisations receiving funding for ECEC within the ROI. Each government department, semi-state body and stand-alone organisation has their own budget, agenda, priorities, and interests, or lack thereof, in early childhood. In recent years, unions, and other representative bodies, for example a group representing owners of EC settings, have begun to enter the arena adding a further density in an already complex space. Intensive campaigning and advocacy by not-for-profit organisations have also strongly influenced ECEC policy development in ROI. A range of grassroots organisations and NGOs, including Early Childhood Ireland, The National Women's Council of Ireland, and two major coalitions the Start Strong Coalition and the Children's Rights Alliance keep ECEC high on the political agenda, and produce research reports often critical of government action (Lloyd, 2023).

3.2.1 Market Model of Early Education

The ECEC sector in Ireland developed in an unplanned fashion and, to this day, provision includes a mix of home-based childcare; private for-profit services and not-for-profit community services typically found in DEIS [Delivering Equality of Opportunity in Schools] areas. Over time, ECEC services were created to meet local needs but were unregulated and unsupported by government funding until the early 1990s (Hayes, 1995). The system that developed therefore, followed the market model. Characterised by positioning early childhood education as a private business (Lloyd & Penn, 2014) the market model assigns public provision to private providers 'distancing policy makers from any direct responsibility for the quality of the actual provision of services' (Hayes & Urban, 2018a, p. 126).

A clear prioritisation of education over care within the 'split system' in the Republic of Ireland is widely acknowledged (Bernard et al., 2020; ECI, 2020; Moloney, 2010; Moloney & Pope, 2015; Urban, 2019; Wolfe et al., 2013). This split system sees compulsory education, under the auspices of the Department of Education, begin at six years of age. However, the first two years of compulsory education, led by graduate primary school teachers, are available to children from the age of four and until recently, it was commonplace for children to start school at this age. Since the introduction of a state-funded, part-time preschool service in 2010, almost all children now start compulsory education at five having availed of this service (Smyth, 2018).

In contrast, elements of ECEC provision prior to compulsory education have been the responsibility of a series of Government Departments including health, justice, welfare, education, and children and youth affairs (Walsh, 2017, 2018). Since 2010, children from 2 years 8 months are entitled to 15 hours of government funded preschool provision per week. This is provided by private providers and subsidised by the State. These providers are subject to health and safety inspections through Tusla, the child and family agency in Ireland; education inspections through the Department of Education; and compliance and funding inspections through Pobal.

Provision for babies and toddlers continues to be limited as subsidies for this age-group are based on family income and only awarded for centre-based services, excluding anyone using a childminder. While plans were announced in the 2024 budget to remedy this, it remains an issue as, in recent years, baby and toddler rooms in ECEC have been closing en masse (Brennan, 2023; Brennan & McConnell, 2021; Wilson, 2023). Provision for these age groups is no longer seen as financially viable due to fewer government subsidies for this age range, increased regulation, and lower ratio requirements (Walsh, 2022). When compared to a fully graduate-led workforce in compulsory education, limited qualification criteria for those working in ECEC settings were introduced in 2015. All educators working in an ECEC setting must possess a basic qualification and higher qualifications are required for room leaders and managers. While a subsidy for graduate-led classrooms has been introduced to encourage those with degree qualifications to remain in the sector, this appears to be ineffective, as research identifies that graduates are leaving in search of better pay and conditions elsewhere (Loughlin, 2022; SIPTU, 2022).

Despite a marked increase in expenditure in the ECEC sector (OECD, 2021c) the hands-off approach adopted by the State has remained unchanged and the role in direct EC service delivery remains limited, chronically underfunded, and characterised a lack of coordination (OECD, 2021c; Urban, 2019; Wolfe et al., 2013). Past actions lead to 'path dependence' which informs future policy decisions (Pierson, 2000). Pierson (2000) argues that once introduced, particular courses of political action can be almost impossible to reverse; the costs of switching from one policy strategy to another are often seen as prohibitive and issues of timing and sequence reinforce the status quo. Thus, it would take substantial effort and a clear vision to change from a market model to something akin to public ECEC for all. In contrast to common understandings of education as a public good, the Irish political system still sees ECEC as a business rather than profession (Wolfe, 2015).

3.2.2 Consulting Stakeholders

The State is aware that the disjointed approach to ECEC has a negative impact on quality and the success of policy initiatives. 'Previous initiatives have tended to operate within traditional silos of practice such as health, education, or welfare… it is essential to work collaboratively and support interdisciplinary work practices' (Government of Ireland, 2018, p. 111). Yet, establishment of collaboration with the ECEC sector and the sharing of information remains problematic. The need to work with and consult with the sector has been identified numerous times (Hayes & Duignan, 2017; Hayes & Urban, 2018a; McCormilla, 2018) to create buy-in, draw on expertise and overcome issues unique to the ECEC sector in ROI. The aim of national consultation is to offer diverse stakeholders from practice and policy the opportunity to affect policy decisions and in turn, promote greater cohesion in the delivery of ECEC arising from that policy change (Hayes & Duignan, 2017). In the past, this has been managed successfully (for example see Centre for Early Childhood Development & Education, 2004; NCCA, 2023b) but the fragmented nature of the sector, the number of representative bodies and the pace of policy change make it a difficult and resource-intensive task.

Effective knowledge exchange and knowledge brokering across the spheres of policy, research and practice is required to develop national policy that is in the best interests of young children (Hayes & Duignan, 2017). The ECEC sector should be involved in designing and enacting policy change, something that is even more crucial in the vast and diverse ECEC sector within Ireland. The role the State plays in creating connections with and *between* stakeholders is identified by McCormilla who argues that 'stakeholders should have a clear and agreed vision for children, which should then underpin policy development and implementation at national and local levels' (McCormilla, 2018, p. 88). In essence, if the goals and pathways to achieve those goals were clear to all stakeholders, policy enactments would be simpler. Despite the identification of this issue, concerns have been raised about the scope and pace of reforms in Ireland, and the way in which educators and stakeholders on the ground are consulted and involved (OECD, 2021b). The OECD observes that stakeholders can be ill-informed about ECEC strategies and how specific elements of ECEC plans fit together to form a whole. While acknowledging that this is most likely a reflection of the complexity in responsibility and governance for the sector, they comment that the connections between, and order of different elements of reform are unclear to stakeholders even when planning for public engagement, consultation and coordination have been put in place (OECD, 2021c).

This observation is bolstered by an ECEC policy analysis in ROI which identified a limited interpretation of policy goals, competing rationales informing investment decisions in ECEC, and an unwillingness to enable and empower advocacy within the sector and improve overall coordination efforts (O'Donoghue Hynes, 2012). These issues continue over a decade later. Thus, the dissemination of information about government strategy and provision of effective communication and consultation with the sector is a key part of policy success and should be treated as such. This and other factors influencing policy success are discussed in further detail below.

3.2.3 A System at Breaking Point

Policy enactment is made more difficult by other pressing matters within the ECEC sector in ROI. Settings are under financial strain and the current market model of ECEC has proved to be ineffective (Bernard et al., 2020; Early Childhood Ireland, 2016). Settings are closing in ever increasing numbers (O'Brien, 2022) and in some areas parents face a two-year wait list to access ECEC services for their children (Walsh, 2022). A recent survey of couples with children found that in almost 60% of cases one partner, typically the woman, has had to give up work due to the cost of childcare (Molloy, 2023). Issues that were the focus of policy reform and investment in the 1990s, namely access and affordability, are still posing challenges for families and their children.

As the provision of ECEC is almost fully private, working conditions and continuing professional development are not covered by specific regulations, and the government has few direct policy levers to influence them. Pay and conditions are not the subject of any national regulations or collective agreement but are matters between individual providers and employees (ECI, 2020). Staff turnover is high, and settings have reported recruitment issues since 2018 (Pobal, 2019, 2020, 2021, 2022) attributed in part to poor working conditions in the sector (OECD, 2021b, 2021c). Financial insecurity, lack of basic benefits (sick pay, pension, paid maternity leave), chronic workplace stress, feeling undervalued by society and government, and increasing demands are reported as reasons why educators are moving out of the sector (Greer-Murphy, 2021).

The ECEC sector in Ireland is not perceived as a profession at either a macro (government, society, other pedagogical professions) or micro (local, setting) level (ECI, 2020). Despite this, levels of professional qualifications in the sector increase year on year (Pobal 2021, 2022) in response to increasing qualification requirements. A corresponding increase in salary, recognition, profession status or working conditions is absent (ECI, 2020; Greer-Murphy, 2021; Moloney, 2010, 2015). Post Covid-19 the sector lost many of its workforce (Loughlin, 2022; SIPTU, 2022) and staff attrition remains high. Those with higher levels of qualifications in particular, are actively seeking employment in other sectors (Greer-Murphy, 2021; Ryan, 2021).

Having been subjected to profound reform in the past two decades, the ECEC sector is straining under the pressure of ever-evolving ECEC infrastructure, policy development and emerging professional profile (Bernard et al., 2020; Greer-Murphy, 2021; Holland, 2023; Loughlin, 2022; Moloney, 2021; OECD, 2021b, 2021c; Ryan, 2021; SIPTU, 2022). The sector now appears to be a breaking point. This begs the question; why is the State focused on EC STEM when so many other urgent issues in ECEC provision require attention?

3.3 STEM Policy in Ireland

3.3.1 Changing Priorities.

> 'The political focus on STEM seems motivated by the outcomes of a STEM education, not how to teach or learn about it, or even what STEM really is' (Lovatt, 2020, p. 68).

In the wake of rapid changes to the ECEC sector in Ireland, STEM education has become a priority for the Department of Education (DOE). A series of high-profile policy documents address a perceived need to have STEM included at every level of the education system, claiming that STEM education is 'highly relevant for the state's economic prosperity' and that a national focus on STEM is required to ensure we have a highly skilled workforce (Department of Education and Skills, 2017d, p. 6). STEM education is a key policy priority in the ROI (Department of Education and Skills, 2020a, 2017b; Department of Education and Skills (DES), 2017a, 2017b; Department of Education and Skills, 2020c). Individual STEM discipline areas are not common in ECEC initial education in ROI at any qualification level, and educators report that they need support in this area (O'Neill et al., 2023). The Department of Education has identified that 'further policy initiatives, support and actions are necessary to ensure that practitioners and early learning and care settings are fully supported to engage with the national STEM agenda' (Department of Education and Skills, 2020b, p. 33). However, there is no clear consensus on how to integrate STEM disciplines and processes into ECEC curriculum in Ireland, or the type of teaching practices deemed suitable for children from birth to six years. There is a paucity of research on tailoring EC STEM practice for babies, toddlers and young children in Ireland, and educators state they are unsure how to implement STEM 'in a way that was appropriate to the age of their learners' (Department of Education and Skills, 2020a, p. 26).

Key STEM policies published by the DOE in the last decade include, but are not limited to:

- STEM Education in the Irish School System; A Report on Science, Technology, Engineering and Mathematics (STEM) Education. Analysis and Recommendations (STEM Education Review Group, 2016).
- STEM Education Policy Statement, 2017-2026 (Department of Education and Skills (DES), 2017b).
- STEM Education Implementation Plan 2017–2019 (Department of Education and Skills (DES), 2017a).
- STEM Education 2020: Reporting on Practice in Early Learning and Care, Primary and Post-Primary Contexts (Department of Education and Skills, 2020c).
- Digital Learning 2020: Reporting on Practice in Early Learning and Care, Primary and Post-Primary Contexts (Department of Education and Skills, 2020b).
- STEM Education Implementation Plan Phase 1 – Enhancing report (Department of Education, 2023b)
- STEM Education Implementation Plan to 2026 (Government of Ireland, 2023).

- Review of Literature to Identify a Set of Effective Interventions for Addressing Gender Balance in STEM in Early Years, Primary and Post-Primary Education Settings (Department of Education and Skills, 2020a).
- Recommendations on Gender Balance in STEM Education (Department of Education and Skills, 2022)
- Recommendations on STEM and the Arts in Education (Department of Education, 2023a).

The first STEM document published by the DOE was a review of STEM Education in Ireland (STEM Education Review Group, 2016). The aim of the report was to address 'identifiable deficits' and enhance the quality of the STEM education system. The review was undertaken by an expert working group composed of specialists from STEM education, generally from tertiary education, as well as 'industry figures from world-leading companies including Intel and IBM' (p.13). The scope of the report was confined to Primary and Post-Primary education, which goes some way toward explaining why no expertise was drawn from the ECEC sector, and why educators from early childhood were excluded from the national consultation process that followed its release. Regardless, when the official STEM Education Policy Statement 2017-2026 (Department of Education and Skills (DES), 2017b) and the first of three STEM implementation plans (Department of Education and Skills (DES), 2017a) were published the following year, actions for ECEC were included. Given the confines of the original review, ECEC appears to have been added as an afterthought, with a meagre six of seventy-three actions relating to ECEC. In four instances, broad actions include ECEC alongside other parts of the education system, for example, action 2.1.1 to 'develop guidelines and engagement plan to promote the importance of STEM for early years settings, schools, parents, and learners' (Department of Education and Skills, 2017a, p. 8).

The remaining two actions are explicit to ECEC with the first relating to the professional supports to help support educators' understanding of STEM:

> 'Review the professional development content and training resources of the National Síolta Aistear Initiative (NSAI) to enhance the capacity of early years professionals to support STEM education across early years setting' (Department of Education and Skills, 2017a, p. 9).

and the second outlining planned changes to the ECEC inspection process.

> 'Promote early engagement of learners with high-quality STEM learning experiences through inspection of early years pre-school settings in line with the Early Years Education Inspection (EYEI) Framework' (Department of Education and Skills, 2017a, p. 11).

While the inclusion of ECEC in the STEM policy may have been a late addition, it has already had implications for the sector. In response to the STEM implementation plan, the Early Years Education Inspection tool was amended in 2018 and again in 2022. Updated criteria include outcomes related to 'STEAM' dispositions as well as more specific reference to individual STEM disciplines such as mathematics (DES Inspectorate, 2018; 2022). In the STEM Policy implementation document, the inspectorate has been positioned 'to support, build capacity and monitor the quality of STEM education from early years to post-primary level (Department of Education and Skills, 2017a, p. 6). At present, this is one of very few supports offered to ECEC settings pertaining to STEM. However, the inspectorate is a small team with limited capacity, who visit a small percentage of settings each year.

Further, a textual analysis of Early Years Education-focused Inspection reports from 2020 found that inspectors are focusing on monitoring rather than support or capacity building during these visits. 80% of published reports reference STEM disciplines, but actions advised to support educators and/or enhance capacity appear in only 22% of reports (O'Neill, 2021b). Almost half of the actions advised advocated for the *discontinuation* of practice deemed inappropriate, for example, 'Formal teaching of numeracy concepts need to be replaced by alternative approaches' or 'practitioners are advised to discontinue the use of worksheets'. In a very limited number of cases, inspection reports described how practice *could* be improved in relation to STEM, for example,

> 'During water play practitioners could discuss concepts such as weight, temperature, sinking and floating, during their engagement with children. This will support meaningful opportunities for children to engage with experiences that build positive dispositions towards mathematical understanding and skills' (O'Neill, 2021b, p. 7).

While changes to the inspection system came into effect in 2018, the accompanying national training programme, the National Síolta Aistear Initiative (NSAI), has stalled. In part, the delay can be attributed to the outbreak of Covid 19, when all PD was halted. However, settings continue to be inspected in relation to STEM criteria, something that few understand or have undertaken PD in. STEM PD was scheduled to be delivered within the life of the first STEM implementation plan (2017-2020) but is still awaited. In addition to STEM PD, the NSAI was tasked with 'enhancing the capacity of educators to support STEM in EC' (Department of Education and Skills, 2017b) through the provision of STEM resources. The two national ECEC documents, Aistear the early childhood curriculum framework (National Council for Curriculum and Assessment, 2009) and Síolta, the early childhood curriculum framework (Department of Education and Skills, 2017a) include little to no guidance in relation to STEM.

3.3.2 Defining EC STEM in Irish Policy

As previously discussed, definitions of STEM vary, and are influenced by numerous factors. The definition provided in the STEM Education Policy document for the ROI is lengthy, and addresses STEM as discipline, instruction, field, and career (see Hasanah 2020 for details). The policy states:

> 'STEM education is multi-faceted and goes well beyond the main disciplines that constitute the acronym STEM… STEM education not only involves the teaching of these disciplines and subjects in isolation but also involves a cross-disciplinary approach. It builds on the content knowledge and understanding developed in and across the four disciplines, while acknowledging that all STEM learning activities are underpinned by Mathematics. It also recognises the strong linkage between STEM and Arts education, which fosters design, creativity, and innovation' (Department of Education and Skills, 2017a, pp. 5–6).

The STEM Education Policy definition briefly mentions the arts, but the acronym STEM (rather than STEAM) is used consistently throughout the Department of Education's STEM Policy documents and plans. At the same time, the Department of Education's early years inspection tool refers to STEAM rather than STEM (DES Inspectorate, 2018) and the most recent Department of Education material refers to 'STEM and the Arts' education (Department of Education, 2023a). Curiously, mathematics is singled out for a particular mention within the STEM Policy definition when this is not a term that appears in national

ECEC documents such as Síolta (DES, 2018), Aistear (National Council for Curriculum and Assessment, 2009), or the proposed Redeveloped Aistear (NCCA, 2023a), which favour the term 'numeracy'. It is evident therefore that consistency across policy documents (even those within the same government department) requires attention. Language is important and inconsistency adds to existing confusion in a developing STEM education space.

The importance of individual discipline content knowledge (STEM as discipline) *and* the use of an integrated approach (STEM as instruction) is included within the broad STEM definition in the STEM education policy. This is an ambitious objective, as it requires educators on all points on the education continuum to possess significant STEM knowledge and skills. Discipline-specific knowledge and self-efficacy are required; and building on this knowledge, educators must be able to integrate two or more disciplines and their associated skills, knowledge, and processes (Wan et al., 2021). When taken together, the implications for the EC sector are vast, requiring educators to possess high-level understanding of STEM content and processes. Concurrently, EC educators in the ROI continue to report that they are unprepared to teach STEM subjects, that their initial education and qualifications often omit STEM content and that the number of EC programmes covering *any* STEM-related subjects in ROI are reportedly as low as 10% (O'Neill et al., 2023) and in some cases, the term STEM itself is unfamiliar to EC educators (O'Neill, Gillic, & Winget-Power, 2022). For the current policy definition to be realised, significant focus on STEM in initial education, professional development, curriculum development and support services for EC settings are required.

3.4 Policy Success

A poor record of accomplishment exists when it comes to dissemination and implementation of ECEC strategies in ROI (Government of Ireland, 2018; NCCA, 2018; Urban, 2022; Wolfe et al., 2013). There is an increasing acknowledgement that within complex and messy political systems, policy design and enactment does not succeed or fail on its own merits (Hudson et al., 2019). The STEM Education Policy success can be attributed to several issues. Clarity of goals, complexity of the implementation strategy and commitment to funding are factors that often affect policy success (Rizvi & Lingard, 2010) i.e. meeting the goals of the policy as laid out in the document. Overly optimistic expectations and inadequate collaborative policy making have also been linked to the policy-implementation gap and policy failure (Hudson et al., 2019).

3.4.1 Clarity of Goals

The clarity of the goals of any policy, and the potential for their effective operationalization, are factors which significantly affect the likelihood of policy success (Rizvi & Lingard, 2010). The most basic goals in the STEM policy statement are described under four pillars 1) Nurture learner engagement and participation, 2) Enhance early years practitioner and teacher capacity, 3) Support STEM education practice, 4) Use evidence to support STEM (Department of Education and Skills, 2017a). Each pillar has supporting outcomes. For example, Outcomes for Pillar 3, Support STEM education practice include, in part: 'Teachers and learners will have access to relevant, high-quality and up-to-date curricula across all of the STEM subjects and areas at early years, primary, junior cycle and senior cycle levels' and 'Early years practitioners and teachers will have ready access to examples of highly effective practice in STEM education through: advisory visits from the Department's Inspectorate and support services; online materials and publications;

professional networks and online communities of practice' (Department of Education and Skills, 2017a, p. 15)

In an attempt to provide clarity, objectives and high-level actions are identified in the STEM education policy statement (Department of Education and Skills, 2017a). The accompanying implementation plans provide further detail including sub actions, proposed completion dates, and list parties responsible for each action. See **Table 3.1** for an example of objectives and associated sub-actions.

STEM Policy Strategy (2017)			STEM Implementation Plan (2017)	
Pillar	**Objective**	**High Level Action**	**Sub-Actions**	**Named Responsible**
Enhance teacher and early years practitioner capacity	Building early years practitioner and teacher capacity through continuous improvement	Provide a variety of high-quality STEM related opportunities for early years practitioners and teachers to support their own professional learning	Provide a quality assured programme of professional development support for STEM across the support services.	DES, Support Services, SFI
			Develop and share quality assured exemplars of highly effective STEM learning experiences for all learners from early years to post-primary including good practice videos, case studies and sample portfolios.	DES, DCYA, NCSE, NCCA, Support Services
			Review the professional development content and training resources of the National Síolta Aístear Initiative (NSAI)to enhance the capacity of early years professionals to support STEM education across early years settings.	DES, DCYA, NCSE, NCCA, Early Years Support Services

Table 3.1 – Example of relationship between strategy objectives, high-level actions, and Implementation plan sub actions.

In summary, the first two STEM policy documents from 2017 alone contain:

- Four pillars.
- 22 Outcomes (across four pillars).
- 9 Objectives (across four pillars) and 26 high-level actions associated with these objectives.
- 74 sub-actions (across 26 high level actions).

I argue that clarity of goals, and a clear designation of responsibility for these actions is ambiguous from the start. The sheer number of objectives, actions and sub-actions is impenetrable. Multiple agencies are named as having responsibility for sub actions, and in some cases, these appear quite arbitrary. For example, in the sub actions outlined in **Table 3.1** some actions are attributed to ‘support services’ and in other actions to ‘early years support services’. Where an EC action is included, ‘early years support services’ don’t always appear, and are not identified specifically. In previous EC policy in ROI, for example *Better Outcomes Brighter Futures* (Department of Children and Youth Affairs, 2014), a lead organisation was identified to ensure goals were met and continued funding / future budgets were contingent on meeting these goals placing an onus on the lead to ensure goals were met in a timely fashion. However, in this instance no one person is responsible which will impact policy success as the division of responsibility among so many actors have been cited as problematic (Hudson et al., 2019). In their recent research they suggest that collaborative policymaking is, for the most part, relatively weak and remains one of the key reasons for subsequent implementation difficulties. The number of players involved in a strategy can impact success as core ideas get watered down, guidelines are adapted to fit local contexts, and practices shaped to enable enactment (Hudson et al., 2019; Sausman et al., 2016).

Progress of the STEM policy actions to date has been difficult to confirm. The STEM Education Policy Statement covers the dates 2017-2026, with three implementation phases within this timeframe; 2017-2019 enhancing; 2020-2022 embedding; and 2023-26 realising. Due to the impact of COVID-19, the 2017-2019 enhancing phase was extended to 2022, merging the first two stages together (Department of Education, 2023b; Government of Ireland, 2023) and a review of the first implementation phase was published (Department of Education, 2023b). This review listed several *completed* actions including the provision of a series of freely available short, self-directed bite-sized PD opportunities on AistearSíolta.ie, the development of PD in EC STEM ready to be piloted, changes to the Early Years Education Inspection Tool; and the review inspection reports highlighting examples of STEM education which has 'informed further actions in relation to the progression of STEM in ECEC' (Department of Education, 2023b, p. 17). When looking at these points individually, reporting these actions as complete is misleading. For example,

- *A series of freely available short, self-directed bite sized CPD opportunities on AistearSíolta.ie* are available, but even highly qualified and experienced ECEC educators report that they are unfamiliar with these resources (O'Neill et al., 2023)
- *The development of CPD in EC STEM to be piloted in 2023*. This material has been developed but the pilot process has been put on hold. As of May 2024, the pilot has yet to begin. It is unknown when a national rollout may start.
- *Changes to the Early Years Education Inspection Tool and processes.* This has been enacted. Since 2018 ECEC settings are inspected based on STEM/ STEAM criteria. As discussed above, feedback in relation to STEM in these inspections often point out

practice that needs to be changed rather than providing support to understand STEM in an ECEC context (O'Neill, 2021a)

- Finally, a *review of inspection reports highlighting examples of STEM education which has 'informed further actions in relation to the progression of STEM in ECEC'* (Department of Education, 2023b, p. 17) has been published. This review labelled ECEC provision in relation to STEM as 'less than satisfactory' (Department of Education and Skills, 2020c) and stated that further support was necessary if any change was to be expected.

ECEC policy and its implementation in ROI has been heavily criticised in the past (Bernard et al., 2020; Hayes & Urban, 2018a; O'Donoghue Hynes, 2012). The lack of clarity in these documents makes it difficult for any of the responsible parties to be held to account if actions are only partially, or not completed at all. When government policies are ill-defined, it is likely that those policies will be ineffective (Donahoe, 2013). It is admirable that actions within an implementation plan are assigned to specific government departments or support services. However, there is no acknowledgement or explanation for why these actions pertaining to ECEC have not been completed and/or assessed for impact.

3.4.2 Complexity of Implementation Strategy

The complexity of a given implementation strategy, or as Hudson et al (2019) frames it, the estimation of the delivery challenges, requires careful consideration if a policy is to succeed. I've identified a number of factors that shape and influence implementation including the exclusion of EC STEM experts [or EC experts] from steering committee and consultation panels; the lack of accommodation for the difference between EC and later stages of education considered in the policy; the oversight in connecting aims of the policy with EC professional award criteria and the identification of mentors, trainers and lecturers with the skills and knowledge to support the delivery of these aims and actions in ECEC within the lifetime of the policy.

Firstly, ECEC expertise was not sought when devising policy goals (Department of Education and Skills, 2017c; STEM Education Review Group, 2016). ECEC representatives are not on the steering committee and were not consulted in the development of the first implementation plan. Lack of consultation at point of design has led to an initiative that is not fit for purpose, as the rationale and values informing the design of ECEC policy does not reflect that of the sector at large. ECEC requires a nuanced approach, deep understanding of the principles of early childhood education and how these differ from later schooling. ECEC acknowledges the integrated nature of learning, crucial role of context and, perhaps to our detriment, much of our pedagogy is tacit making it difficult for others to understand. In post-primary and third-level education STEM is taught in subject specific disciplines, unlike the approach adopted in ECEC. While there are moves to a more integrated approach in the upper levels of education, its implementation in a holistic way is problematic 'STEM as a renovated approach is gaining ground, despite the infancy of its philosophical analysis. Explicit epistemological discussion of integrated STEM proposals is either absent or blurred' (Ortiz-Revilla et al., 2020, p. 857). Therefore, the 'experts' guiding clarity of goals are not sufficiently informed to make crucial decisions about EC STEM. A key pillar of the STEM policy statement (Department of Education and Skills (DES), 2017b) is to use evidence to support STEM, however this has not occurred in relation to EC STEM practice. Accordingly, many plans, training ideas and actions are not suitable for ECEC and may fail. This failure impacts children, educators, their families, and communities. This factor is a challenge that was not afforded sufficient forethought.

Secondly, much of the STEM implementation plan pertains to staff knowledge and understanding of STEM. Since 2019, ECEC degree programmes must conform to professional award criteria and guidelines (Department of Education and Skills, 2019). Although published *after* the STEM policy and implementation plan, and by the same government department, the terms ’STEM’ or ‘STEAM’ do not appear in these guidelines. Some individual STEM disciplines are referred to, deeming the ability to generate ‘an appropriate curriculum that stimulates and promotes positive learning dispositions, emergent literacy, maths, and science skills’ (Department of Education and Skills, 2019, p. 17) as an essential learning outcome for ECEC degrees. This is the full extent of reference to STEM or its disciplines in the new awards criteria. Nevertheless, the STEM education policy identified an ambitious vision for early years educators that would require a substantial professional development programme for educators. The aim is for ECEC educators to:

> ‘have an excellent understanding of STEM disciplines, methods and processes; provide effective and engaging STEM teaching, learning and assessment; provide collaborative environments, both in and out of school, for STEM learning, fostering curiosity, inquiry, persistence, resilience and creativity; ensure the continuing development of their STEM pedagogical content knowledge and skills in and across the four disciplines; share STEM practice in collaborative settings’ (Department of Education and Skills, 2017a, p. 13)

While this is an admirable vision, without conditions that mandate higher education institutes to include STEM modules (or even basic STEM content) in their programmes, the content and processes required to underpin this learning are likely to be omitted. At present, a limited number of ECEC programmes in ROI include any STEM content and many educators report that their initial education has not enabled them to support STEM in ECEC (O'Neill et al., 2023). The research shows that long-term, flexible, and tailored approaches are beneficial in ECEC (Rogers et al., 2020a, 2020b). It remains to be seen if this will be reflected in the EC STEM PD approach adopted by the State.

A further challenge pertaining to the inclusion of STEM in initial education and PD exists. The responsibility of supporting educators to understand, implement and value concepts and issues related to EC STEM often lies with mentors, teacher educators or those responsible for PD. As EC STEM is not traditionally a part of early childhood education, it is unclear whether teacher educators have the necessary knowledge, skills, and attitudes to competently share this information, although research in ROI is underway investigating this point (O'Neill, Gillic, O'Reilly, et al., 2024). Those teaching EC educators have been a foundational support structure in the many educational reforms over the past two decades. The knowledge and skills of educators is considered critical to the quality of the nation's education system and educator's initial education is assumed to be a central factor in teacher quality (Cochran-Smith et al., 2020). Further, the beliefs and competencies of those teaching in initial educator preparation and PD influence the next generation of educators. How they design and implement coursework, the topics they choose focus on and the philosophy that underpins their practice will be exemplified in their teaching practice

(Cochran-Smith et al., 2020), but anecdotal evidence suggests that many in lecturing and support roles are wary of STEM.

3.4.3 Commitment to Funding

This appears to be another challenge overlooked as the STEM policy was designed. There is no commitment to funding for ECEC settings to support the enactment of sub actions outlined in STEM documents, actions identified to enable educators to successfully meet the goals of the policy. As previously discussed, the research suggests that educators need to upskill in relation to STEM to be able to meet the expanded requirements arising from these policies.   A commitment to funding for primary and post-primary arising from the first phase of the STEM implementation plan (2017-2022) was not extended to ECEC settings, for example, €210 million for Schools ICT Infrastructure Fund. The new STEM implementation plan 2022-2026 states that a programme of work has been designed including 'Provision of funding to support projects that engage children and young people in STEM in primary and/or post primary schools' (Government of Ireland, 2023, p. 7). Once again, ECEC funding is absent.

Communities where EC teacher educators and EC educators can learn about STEM concepts and approaches are invaluable. Learning communities can play an important role in providing support for faculty members to try out new teaching methods, engage in pedagogical innovation and interact with others as they explore new ideas (Kanipes et al., 2019). The establishment of learning communities has been suggested by teacher educators interested in STEM (O'Neill, Gillic, & Winget-Power, 2022) and this proposal has appeared as an action in the most recent STEM implementation plan. The action aims to enhance early years educator skills by providing an opportunity for educators to collaborate and share knowledge (Government of Ireland, 2023). However, these types of support must have a viable funding model. As O'Neill et al., (2023) point out, these structures are labour and resource intensive and need leadership steeped the ECEC community to be relevant.

The treatment of ECEC as a separate entity within the education sector is acknowledged by the Department of Education, author of all aforementioned STEM policy and implementation plans. They note 'Further policy initiatives, support and actions are necessary to ensure that practitioners and early learning and care settings are fully supported to engage with the national STEM agenda' (Department of Education and Skills, 2020b, p. 33). However, no funding has been committed to enact this. Agreement or guidance on what or how STEM should be implemented in ECEC is absent within current policy documents (O'Neill, Gillic & Winget-Power, 2020) and lack of funds exacerbates this. It has been strongly recommended that governments invest in development of high-quality PD for ECEC (Rogers et al., 2020a), and provide support to improve pedagogical knowledge, understanding and skills of ECEC educators that is easily accessible.

Clarity of goals, complexity of the implementation strategy and commitment to funding are the factors that affect policy success (Rizvi & Lingard, 2010). I argue that the ambiguous goals, absent professional development plan and funding could lead to ineffective policy implementation. This remains problematic as it comes at a time when coordination and clarity of ECEC policy could be achieved.

3.5 Influencing ECEC Guidelines

The EC sector in Ireland is at a turning point. Investment is higher than ever before in the history of the state (An Roinn Leanaí, Comhionannais, Míchumais, Lánpháirtíochta agus

Óige, 10 Oct 23) and a myriad of new policy and support documentation is imminent. Aistear, the Early Childhood Curriculum Framework (National Council for Curriculum and Assessment, 2009) and the National Literacy and Numeracy Strategy are currently being redrafted, with both expected to be published by mid-2025. The workforce development plan for ECEC outlines actions to improve training and professionalisation of the sector (Government of Ireland, 2022). These documents provide core guidance on curriculum and pedagogy in ECCE and each will cover at least a ten-year timespan. Targets and objectives in these documents affect the sector in many ways, for example, funding awarded to ECEC settings, support structures and PD projects, and often reflect government priorities. As discussed, policy documents in relation to ECEC often use different terminology across government departments or omit its discussion entirely. As the development of so many influential ECEC documents is underway, there is an opportunity to reach consensus on EC STEM and use consistent language and definitions across all government ECEC policy and documents. I argue that in some small way, this will lead to less confusion. I outline each of the forthcoming documents and current indications for how or if they will refer to STEM and its constituent parts.

In 2021, the National Council for Curriculum and Assessment announced plans to redevelop Aistear, the early childhood curriculum framework for Ireland (NCCA, 2009). Preparatory documents for the *new primary curriculum* suggest that STEM will feature more prominently (NCCA, 2023c) and it appears that changes are being made to Aistear to reflect this. A literature review to support Aistear's redevelopment recommends a stronger focus on EC STEM (French & McKenna, 2022) and this has been enacted in proposals for the new curriculum framework (NCCA, 2023a). Aistear's four themes have been updated to include greater reference to STEM, as according to the new draft document, children enjoy exploring and testing out STEM concepts and ideas.

At the same time, the National Literacy and Numeracy Strategy is being updated. Originally devised in 2011 in response to poor PISA scores, the strategy sets a clear vision for raising standards in literacy and numeracy in early years, primary and post-primary settings (Department of Education and Skills, 2011). A comprehensive review of literature has been undertaken to support the strategy's redevelopment. In early childhood, recommendations have been made to increase math provision in EC (O'Neill, Gillic, & Kingston, 2022). The role of adults is signalled as key to this action. Understanding of math content knowledge is highlighted as well as knowing how to communicate mathematical ideas in a relevant and meaningful way to young children (O'Neill, Gillic, & Kingston, 2022). Further it is stated that EC educators require access to PD in mathematics teaching and learning to enhance this mathematical knowledge and support the development of children's fundamental maths skills in a child-led, play-based environment. In addition, the literature review outlines the complexities of supporting young children's digital literacy. Similarly, the educators' role in advocating for the appropriate and optimal use of technology with young children is highlighted (Dwyer et al., 2022), as is the complexity of incorporating digital literacy into the ECEC setting in meaningful ways to 'design and create authentic collaborative learning spaces' (Dwyer et al., 2022, p. 4). Thus, the knowledge and skills of the educator have been highlighted.

Finally, the ECEC workforce development plan is under review with responsibility for this resting with the Department of Children, Equality, Disability, Integration and Youth, (DCEDIY). Draft terms of reference have been published (DCEDIY, 2019). Several action points are particularly relevant to this study as they pertain to plan for the national professional development system. However, the only reference to STEM/ STEAM within the document appears in the appendices referring to another government document.

3.6 Conclusion

The ECEC sector in Ireland continues to be less aware of the importance of STEM compared to primary and post-primary schools, and STEM practice in a third of ECEC settings is deemed less than satisfactory (MacCarthaigh, 2020). Recent research in ROI demonstrates that ECEC educators are enthusiastic about STEM, but many continue to report that their initial education did not prepare them to support children's early STEM learning (O'Neill et al., 2023). Further, educators are particularly unsure about the suitability of STEM experiences and content for babies and toddlers (O'Neill, 2021a; O'Neill et al., 2023). Considering that the ECEC sector at large has had little focus on STEM in their initial education and that PD is lacking, the inclusion of STEM (and its constituent parts) in so many ECEC documents appears premature. While some excellent support has been made available, for example, materials on aistearsiolta.ie., a significant number of ECEC educators report that they are unfamiliar with these (O'Neill et al., 2023). Acknowledging that changes to these policy documents, STEM PD and other support are forthcoming, it is an ideal opportunity to seek advice from the ECEC sector about whether they consider EC STEM to be appropriate and if so, what *would* work to support their STEM pedagogy. If a consensus was drawn from expertise in ECEC in Ireland and beyond, this information could be used to inform the development of these policy documents and any training or support put in place to enact them. What's more, the recommendations proposed would be based in the philosophy and traditions of ECEC and consider the challenges inherent in that system. The methodology and methods to support this idea are outlined in the next chapter.

Chapter 4 – Methodology and Methods

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4.1 Introduction

This chapter presents the research methodology and methods. It outlines how methodological decisions were made to form a congruent approach with the underpinning ontology/epistemology of the study. It provides a rationale for the paradigm employed; the approach to generating and analysing the data; the research design and methods utilised. To construct the research methodology, it was necessary to consider the study's underpinning research question 'how should STEM education be implemented in ECEC in ROI?' I begin by clarifying aims, objectives, and research questions before outlining my positionality, the ontological and epistemological assumptions and orientations which guided the study, an explanation of the methods chosen and strategies applied to analyse the data. Finally, I discuss the ethical considerations and possible limitations of the research methodology.

4.2 Aims, Objectives, and Research Questions

The aim of this study is to explore how STEM education should be supported in early childhood education and care (ECEC) in the Republic of Ireland (ROI). The objective is to identify what are the key factors that might influence this. As such the following research questions guide this study:

1) How should STEM education be implemented in ECEC in Ireland?
2) What key skills, knowledge and dispositions do ECEC educators require to meaningfully support EC STEM?
3) How could / should educator capacity in relation to EC STEM be enhanced?

4) What professional development opportunities do educators need to meaningfully implement STEM in ECEC settings?

4.3 Methodology

This section will outline influential factors around research related decision-making processes, the assumptions that are made, and my approach to data analysis. My personal interests, goals and experience, and their influence on the conceptual frame, are outlined. My positionality and the way this has influenced the decision to explore this topic, the research questions and decisions throughout the research process is addressed. An overarching argument for a piece of research includes why it is worth doing and how it should be done (Ravitch & Riggan, 2017). Key elements include 1) contribution to knowledge 2) that a study reflects important aspects of research tradition and 3) it identifies gaps in knowledge leading to viable research questions (Marshall & Rossman, 2011; Maxwell, 2020). Maxwell (2020) suggests that conceptual frameworks are built based on a combination of theory, prior research, and experiential knowledge.

As such the methodology section that follows will address my positionality, ontological and epistemological approaches and provide a rationale for selection of thematic analysis method, Delphi method and sampling strategy.

4.3.1 Positionality

As positionality influences the design and direction of a study *and* shapes its development (Rogers, 2016), I outline my personal goals, starting points, and identity. I'm an assistant professor of early education in a university in the Republic of Ireland. I teach STEM subjects to pre-service early educators including technology in early education, early mathematics, early STEM/ enquiry-based learning, as well as children's rights. I possess no desire to force this content onto others. My students engage with materials, processes and literature and make their own decisions about what works for them in their practice. In fact, I have concerns about the push-down of academic subjects into ECEC in ROI. One of the drivers for this study is my apprehension that the STEM that will appear in EC settings will be formal, directive, and content- rather than process- focused. STEM in EC is not an imperative and it is not our core business (Fleer, 2019). But it *has* been made a requirement for EC settings in ROI (DES Inspectorate, 2018) and both educators (Department of Education and Skills [DES], 2016; O'Neill et al., 2023) and the Department of Education have identified the lack of understanding in relation to STEM and the need for further training and supports (Department of Education, 2023; Department of Education and Skills, 2020). I argue therefore, that a clear vision for these supports and uniform conceptualisation of what EC STEM should be in ROI are necessary starting points if this policy position is to continue.

This study could be labelled as insider research (Bukamal, 2022) as I have worked in the EC sector in ROI for 20 years in various guises including as an EC educator, manager, mentor, trainer, researcher, in curriculum development, PD design and now as a researcher and academic. For a number of years, I worked in curriculum and policy development where my role required me to work closely with senior civil servants and policy makers in government departments, national mentoring organisations, inspection, policy and support (see figure 3.1 on p.79 for details of the ECEC structures in ROI). I worked alongside those who were making decisions about policy and curriculum and saw first-hand how policy and curriculum is envisaged, designed, developed and the amendments that are made as it moves through a process of review and refinement before it ever becomes public. Often what is published pales in comparison to the initial conceptualisation. In my experience, most policy is nothing more than compromise captured on paper. In addition to this, I worked to disseminate changes to policy and curriculum with those in mentoring, inspection and support roles and offered assistance, guidance and developed tools to enable them to communicate these changes with educators in practice. I share many attributes with the participants of the study and know almost all of them personally so meet the criteria as an 'insider' researcher. My background in policy and curriculum development offers a unique insight to the research and unprecedented access to may who have the power and influence to make policy decisions. This provides opportunities, as a personal approach has been found to result in a positive response to requests to participate in research (Day & Bobeva, 2005). When compared to the ability of others, my insiders background in and knowledge of the research context, allows me to prepare, interpret and ground events in the research context (Bukamal, 2022; Easterby-Smith & Malina, 1999). Being steeped in the sector, knowing how policy decisions are made and who is included in consultation (and who is often excluded) allows me to frame this research in a meaningful way. This knowledge and experience of the sector could be interpreted as bias, but I view this as a strength of my position, as I possess a comprehensive understanding of the workings of the sector that other researchers could not.

4.3.2 Ontological and Epistemological Approaches

Ontology is 'assumptions about the nature of reality and the nature of things' (Cohen et al., 2011 p.3) and the starting point from which epistemological and methodological positions follow (Grix, 2002). Assumptions about the world around us, how things really are and how they work, are closely linked to ideas about how to *find out* about the world (Mukherji & Albon, 2018). Epistemology is concerned with this second point; how to find out about the world around us and is defined as 'ways of researching and inquiring into the nature of reality and the nature of things' (Cohen et al., 2011 p.3). Epistemological assumptions guide what a researcher assumes to be valuable or useful knowledge. This steers individuals toward certain types of research, which in turn impacts aims, objectives, design, data collection, analysis, and interpretation of results (May, 2011). Thus, my ontological and epistemological positions are important to acknowledge as they influence my assumptions about the nature of reality, knowledge, and how to gather and understand data.

Positivist research is concerned with uncovering an underlying order of universal laws, explaining, and predicting cause-and-effect relationships between random events (MacNaughton et al., 2001). Confirmatory approaches, the search for universal laws that apply to entire populations, precise measure, the use of structured and validated tools, and the focus on statistical relationships are common within this research paradigm (B. Johnson & Christiensen, 2012). The application of highly controlled procedures and the quantifying theory can help refine theories, lead to more generalisable findings that are considered valid and replicable due to tight controls and strict adherence to the scientific method, and are particularly valuable in EC when investigating large cohorts (Mukherji & Albon, 2018). Yet, in my experience in working with children, families, and communities, there is no single correct answer to any question. In EC education, the response depends on the child; their family structure, support structure, experiences, and resources; their community; national policy, legislation, and funding; and culture and traditions. For this reason, I favour an approach to research which acknowledges that there are multiple explanations for actions and is interested in the meanings people ascribe to their actions.

Interpretivist research postulates that we 'create and recreate our social world as a dynamic system of meanings by continually negotiating with others the meanings of our actions and circumstance and theirs, and the meanings of social and cultural institutions and products' (MacNaughton et al., 2001, p. 271). This research paradigm defines research as an interpretative process that enables the making of meaning rather than the discovery of meaning (Ravitch & Riggan, 2017). Adopting an interpretivist approach will enable me to examine the subjective intentions, beliefs, and meanings (Pring, 2010) ascribed to EC STEM by multiple stakeholders in ROI, each of whom have an important role to play in the EC STEM landscape. This ontological perspective holds that the social, economic, and political contexts lead to multiple socially and culturally constructed realities. I argue that STEM in ROI is seen through a cultural framework that includes early childhood, and the socially constructed and shared meaning associated with the Irish Education system. These interpretations influence behaviour and, in turn, have an impact upon the world (Mukherji & Albon, 2018). It is these interpretations and associated actions [or inaction] that interest me. Thus, I have adopted a broadly interpretivist approach to this study.

4.3.3 Data Analysis Technique

To answer the research question 'how STEM education should be supported in early childhood education and care (ECEC) in the Republic of Ireland (ROI)', a number of qualitative research methods were considered for this study, including discourse analysis, impact analysis, and ethnographic approaches to exploring EC STEM in ROI.

Discourse analysis was considered as a potential qualitative data analysis method to explore EC STEM in the ROI. Policy texts, STEM position papers, support documents, Department of Education circulars and announcements from EC stakeholders would provide a resource that could be analysed. Similarities and differences, conflict and struggle within texts are drawn out to uncover meaning (Higgins, 2021). In the past scholars have used this technique to review EC public policy, and the messages that accompany them, to highlight inconsistency between policy and practice (for example, see Hayes, 2010, 2015; Hayes & Duignan, 2017; O'Donoghue Hynes, 2012; Urban, 2019). However, this approach would not provide a route toward EC STEM implementation in ROI, a well-defined model outlining key components and ideas, something I felt was important to ascertain.

Impact evaluation of the current STEM policy and its implementation plan could demonstrate how effective the policy has been to date. Impact evaluation in education assesses the effects of policies or initiatives on the education outcomes for learners (Coe et al., 2021). The goal is to examine the impact of the policy and present a summative assessment of the effectiveness of the change (Higgins, 2021). This was discounted due to difficulties in implementing plans due to COVID 19 restrictions. Limited impact assessment carried out by the Department of Education Inspectorate in 2020 identified that implementation of STEM in EC remains poor (Department of Education and Skills, 2020). It should be noted however, that this was an extremely small sample (3 settings of 4,000+ in ROI).

Ethnographic study using a case study design to explore how EC STEM is being implemented in ROI was considered at length. The flexible parameters and opportunity for sustained investment and interest over time (Bhatti, 2021) was attractive. I was / am curious about how current EC STEM practice in ROI relates to the evidence base. Ethnographic study would allow for a deep understanding of STEM practice in a small number of settings, with a particular group of children, and would provide rich examples demonstrating EC STEM. My reluctance to adopt this method was that it would not identify how *other* educators might be supported to engage in similar practice or establish what types of support are required. STEM has been positioned as a social justice imperative (Hachey, 2020; OECD, 2021a) so it is important for all children, in all settings. I want to find an EC STEM 'roadmap' which gives clear instructions about 1) what educators need to know about STEM, 2) what STEM skills they need to have, 3) how might they be supported to gain this knowledge and skill, and 4) identify who is responsible for making this happen in ROI.

Consensus methods enabling the inclusion of a wide variety of EC stakeholders were considered. Surveys that would allow for a larger and more representative sample of the EC workforce, combined with focus groups or group interviews had the potential to answer, 'how STEM education should be supported in ECEC in ROI'. On the one hand, focus groups can uncover collective perspective, involve diverse groups, and include potentially large numbers of stakeholders; on the other hand, they can be difficult to organise, manage and produce complex verbal and non-verbal responses (Coe et al., 2021). The purpose of consensus methods is to define levels of agreement on contentious subjects (Fink et al., 1984). The outputs are considered to be more justifiable and credible than other methods that include wide consultation of individuals or committees (Fink et al., 1984). The strength of these methods lies in the opportunity that group decision-making provides. It brings a wide range of knowledge and experience to the question at hand, allows equal consideration of multiple perspectives and can challenge long held perceptions. In essence, consensus methods claim to provide a framework to support the democratic representation of a wide range of opinions (Humphrey-Murto et al., 2017).

Having examined several approaches, consensus methods were chosen as the most appropriate way of answering the research question. Considering multiple methods clarified what was important for me to achieve with this piece of research. Having a shared vision within EC (McCormilla, 2018) using research to support policy approaches (Hayes & Duignan, 2017) without contributing to an agenda that positions educational research as a pawn for policy objectives (Hammersley, 2002) and to combat issues arising from rapid policy implementation and subsequent confusion (OECD, 2021b) began to take centre stage. The concept of a roadmap or action plan for EC STEM began to emerge; a plan agreed with input from key stakeholders looking at all areas in relation to EC STEM (definitions, key skills, actions, supports at local and national level). This method would include policy makers who do not have a background in EC or EC STEM and expose them to expert opinion without risking exposing this lack of expertise.

4.3.4 Rationale for use of Delphi in this study

The Delphi technique was originally developed by the RAND corporation in the 1960s to explore issues of national security during the cold war (see Dalkey & Helmer, 1963). The method sought to address complex questions in areas of uncertainty, in this instance military response to attacks on positions of strategic importance. Expert opinion on a topic was considered an acceptable second choice when knowledge was imperfect and there were no easy answers or hard facts (Donohoe & Needham, 2009). The Delphi technique is characterised by four methodological elements i) a panel is identified with expertise in the specified area ii) the process is anonymous to avoid bias or the influence of 'groupthink' iii) an iterative review process is undertaken, typically with several rounds of surveys on the same topic iv) each subsequent round builds on information gathered in the previous round, refining and expanding expert responses to build consensus (Geist, 2010; Jünger et al., 2017; Pearson et al., 2017; Rowe et al., 1991; Rüetschi & Olarte Salazar, 2020; Saffie et al., 2016). Multiple versions of this technique have been adapted and successfully used for empirical research (Rüetschi & Olarte Salazar, 2020). What follows is a description of the core characteristics and how this method is tailored to best meet the requirements of this study.

Four main characteristics need to be satisfied for a procedure to be considered a Delphi technique: the creation of an expert panel, anonymity, iteration, and statistical aggregation. Each of these will be discussed in turn.

1. *Panel creation.* The design and formation of the expert panel are important factors in Delphi studies. Panellist selection has been described as the 'lynchpin' (Iqbal & Pipon-Young, 2009) of the technique and the most critical design decision (Day & Bobeva, 2005; Donohoe & Needham, 2009; Iqbal & Pipon-Young, 2009;Powell, 2003). Prospective panel members are carefully selected for their expertise in some aspect of the topic under study (Gordon & Pease, 2006).
2. *Anonymity.* A strength of the Delphi method, when compared to other consensus methods, is anonymity (Rana et al., 2018). Anonymity is used to counter the disadvantages of other consensus methods, such as round-table discussions, as it is 'more conducive to independent thought on the part of the experts and to aid them in the gradual formation of a considered opinion' (Dalkey & Helmer, 1963, pp. 458–459). They argue that direct confrontation encourages participants to 1)

close their mind to new ideas, 2) defend the stance they initially take, 3) jump to preconceived notions and /or 4) be swayed by the opinions of others. Personal characteristics and group dynamics can lead to difficulties in face-to-face meetings (Rowe et al., 1991). Social pressures, group think, getting side tracked or domination by more vociferous group members may contribute to bias. In Delphi, panellists are unaware of the identities of others, mediating some of these difficulties. Experts can reflect solely on an issue's merits without influence from other group members. Direct confrontation between experts is averted and more junior members of the group are less likely to acquiesce to the opinions of senior members (Geist, 2010; von der Gracht, 2012).

3. *Iteration.* The repeated individual interrogation of the experts is integral. Typically, participants are sent a series of questionnaires centred around a key topic or problem (Dalkey & Helmer, 1963). Statements or queries related to this problem are posed and expert response analysed. This process is continued several times (referred to as rounds) until consensus is reached or until criteria outlined in the research design is met. The process of iteration leads to more accurate results as less knowledgeable panellists are swayed by the more resolute (Linstone & Turoff, 1975). This is demonstrated by **Figure 4.1**. Theoretically, the less adamant and knowledgeable members of the group will realise they are outside the norm, waver, and be drawn toward the median; while the confidence of the most knowledgeable panellists ensure they are less drawn toward the mean and remain steadfast in their opinions (Rowe et al., 1991).

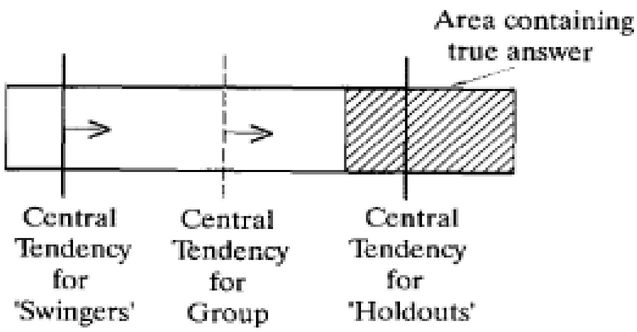


Figure 4.1. Theoretical change in group response over rounds (adapted from Rowe et al, 1991).

4. *Aggregation of data.* In a Delphi study, the expert panel receives feedback between rounds. It is recommended that both qualitative comments and quantitative information, such as statistical measures, are shared with experts (Murphy et al., 1998). The data assists experts in making decisions in future Delphi rounds by apprising each participant of their position relative to the rest of the group (Boulkedid et al., 2011). While opinions vary about the level of detail required, feedback is generally comprehensive. For numerically answered questions the mean or median of responses, lowest and highest ratings, the participant's responses should be shared after each round, as well as a summary of all comments received and reasons furnished by participants for holding extreme positions (Boulkedid et al., 2011; Gordon & Pease, 2006). von der Gracht (2012) expands on this list maintaining that statistical group responses should include measures of central tendency (median, mean), dispersion (interquartile range, standard deviation), and frequency distributions (histograms and frequency polygons), presented numerically or graphically. This information allows each expert to see where their position lies on the continuum of opinion.

> In addition to statistical data, experts are often furnished with sample comments, queries, or suggestions from other panellists. After reviewing this information, panellists can decide whether to change their position or remain steady. Where a panellist's position greatly deviates from the group, they are encouraged to give a rationale for their exceptional opinion (von der Gracht, 2012)

There are several reasons why the Delphi method is a good fit for this study. The study aims to generate a clear vision for EC STEM in ROI. Delphi differs from surveys which focus on what is, by trying to determine what should or could be (Hsu & Sandford, 2019). The aim of this study is to solve multiple problems I perceive with EC STEM in ROI and identify how they could be resolved. The early childhood workforce in ROI is small, approximately 4000 people (Department of Children, Equality, Disability, Integration and Youth, 2019). Those in policy, research and support positions make up an even smaller percentage of the overall number. These individuals have a wide professional cross-over, as people move between a relatively small number of professional organisations, faculty, or government departments responsible for, or interested in, EC in ROI. Individuals can be easily influenced by those who are in, or who are perceived to be in, higher or more authoritative positions. Therefore, the anonymity involved in the Delphi technique is useful in enabling panel members to express their opinions freely.

Dalkey and Helmer (1963) opine that the iterative nature of the Delphi process and the sharing of aggregated data challenges individuals' misconceptions about a particular topic and forces them to explore factors that influence their decision making. In this study, international and national EC STEM experts are canvassed alongside individuals likely to be making decisions about upcoming EC STEM implementation or support projects. This process has the added benefit of exposing less knowledgeable (but more powerful in terms of policy decisions) panel members to ideas, opinions and approaches they may not have been aware of or considered. This is particularly important as EC expertise was not sought in the development of the original EC STEM policy statement in ROI, and decisions made do not align with typical EC philosophy.

Delphi has been found to be a useful tool to engage multiple participants, bringing all stakeholders together to achieve consensus (Hsu & Sandford, 2007). While this is a valuable aim, without agreements being enacted, the sector will remain in a similar position to when the STEM policy was published in 2017. Involving stakeholders in evaluation increases the attention paid to the findings, increases stakeholders' understanding, promotes participatory and collaborative relationship between stakeholders; and increases the validity of the findings (Geist, 2010). The creation of an expert panel, using the criteria that aligns with the goals of this study, could compel policymakers to pay greater attention to findings and lead to a closer understanding of the issues at hand. It is hoped that this will lead to more meaningful and realistic outcomes in relation to EC STEM policy.

Finally, the Delphi method is popular in international studies as it does not require face to face engagement (Rana et al., 2018; Waggoner et al., 2016) which removes geographic challenges and time boundaries (Geist 2010). The proposed participants include national and international experts who are geographically distributed with a high degree of reliance on online correspondence. In conclusion the method has been chosen as it 'offers reliability and generalisability of outcomes, ensured through iteration of rounds for data collection and analysis, guided by the principles of democratic participation and anonymity… Its iterative feedback method develops an insight, which in its totality, is more than the sum of the parts' (Day & Bobeva, 2005, p. 104). In fact, Fink-Hafner et al. (2019) recognise that many using the method are not truly concerned about representing reality but desire to develop a theory by seeking a consensus among experts to inform such decisions. Delphi enables researchers to depict the social reality of situations based on expert conclusions, rather than primary data (Fink-Hafner et al., 2019). Further, the expert group must reach agreement in a number of ways. Firstly, it must be ascertained to what extent each expert agrees with the issue under consideration and secondly, the extent to which panellists agree with each other (Jones & Hunter, 1995). This can, in theory at least, provide a starting point for further action; a basis for a 'roadmap' or model that clearly articulates EC STEM practice.

4.3.5 Thematic Analysis

Thematic analysis (TA) is a highly flexible approach that can be modified for the needs of many studies. It provides a rich, detailed, and complex explanation of large qualitative data sets as well as be conducted from different philosophical positions due in part to its lack of ties to a particular epistemological or theoretical framework (Braun & Clarke, 2022; Frost, 2021; Nowell et al., 2017). TA presents a way to code data into patterns of meaning or themes using a rigorous multi-stage process that moves from descriptive to increasingly interpretative (Frost, 2021; Langdridge & Hagger-Johnson, 2013).

The *approach* to thematic analysis is influenced greatly by epistemological positioning. A prerequisite of high-quality thematic analysis is a well addressed explanation of epistemology that informs the knowledge being sought, and details why the themes may be significant, and what they may represent in context (Frost 2021). Braun et al (2019b) make a distinction between a variety of thematic analysis approaches outlined in **Table 4.1.** Coding reliability TA and codebook TA approaches are generally but not always, aligned with positivist orientations to confirm the presence of data under pre-existing criteria, or to strengthen the reliability of data by having a number of independent people review the data and to compare results.

In reflexive thematic analysis (RTA) researcher subjectivity is understood as a strength (Braun et al., 2019a; Braun & Clarke, 2019) but only when a researcher's stance and position is explicit. Ontological and epistemological understandings, my own research leaning, and positionality lead me to adopt a qualitative interpretive approach that considers the centrality of researcher subjectivity and reflexivity. The result of RTA illustrates the convergence of the dataset, the analytical skills of the researcher, and the theoretical assumptions of the analysis (Byrne, 2022). When adopting RTA, the researcher’s stance is made clear to enable readers to understand the analysis carried out.

Thematic Analysis (TA) Approach	Used for… Example	Paradigm	Description
Coding Reliability TA	Used as a process for categorising data	Positivist - identify the themes that exist in the data	Assumption- that there is a reality in the data that can be accurately captured through coding, if appropriate techniques are used. Assumption is that the themes exist in the data prior to, and regardless of, the researcher's reflexive engagement with it.
Codebook TA Approaches	Used as a tool for use with other method Includes methods like template analysis and framework analysis.	Positivist - confirmation of results	The emphasis is on the measurement of the accuracy or reliability of coding through the use of a structured codebook and multiple independent coders [inter-rater reliability]
Reflexive TA Approach	Braun and Clarke Used as a method in its own right	Interpretivist - focus on meaning	Reflexive thematic analysis (RTA) regards the processes of coding and development as essential to constructing themes, and the researcher as being central to this process.

Table 4.1. Thematic analysis approaches, adapted from Braun et al., 2019.

Recently Braun and Clarke have updated the way in which they describe their approach to data analysis from 'thematic' to 'reflexive thematic analysis' (Braun et al., 2019b; Braun & Clarke, 2019, 2022) in response to common misapplications of the framework by others (Braun et al., 2019a; Braun & Clarke, 2019). RTA requires the researcher to articulate the assumptions that informed their approach and how exactly they enacted TA. They argue that the flexibility of the approach has been misinterpreted and instead it is viewed as a rigid set of steps or a set of binary choices, for example, semantic or latent coding, inductive or deductive orientation and so on. See table **4.7** for further details.

> 'For us, qualitative research is about meaning and meaning-making, and viewing these as always context-bound, positioned and situated, and qualitative data analysis is about telling stories', about interpreting, and creating, not discovering, and finding the truth that is either out there and findable from, or buried deep within, the data' (Braun & Clarke, 2019, p. 5.)

Reflexive thematic analysis used in this study seeks out meaning in data and understands this as context bound. As Braun and Clarke (2019) explain, qualitative data analysis is about telling stories; positioning, situating, interpreting, and creating. Accordingly, where dissent was identified this was treated as valuable data requiring careful consideration. These stories offer important insights and while they may appear infrequently, represent a smaller number of experts and /or number of experiences they require exploration, consideration and implications discussed. Dissent analyses yield high value and additional insights and the potential reasons for diverging opinions, which is often neglected (Beiderbeck et al., 2021). Absence of dissent analysis is considered a design flaw (Shrier, 2021).

Acknowledging the interpretivist orientation adopted in this study, it is necessary to resist the claim that I or the research is neutral (Lather, 2006). However, regular reflection on how my position and knowledge may unduly influence this study was required. Berger (2015) maintains that reflexivity can support qualitative researchers to understand the role of the self in the creation of knowledge, focus on self-knowledge and sensitivities, and monitor the impact of their biases, beliefs, and personal experiences on their research. This provides opportunities and benefits (Berger, 2015; Day & Bobeva, 2005) but is challenging to think outside my own experiences and education which in spite of our best efforts, normalizes our thinking and doing (Lather & St. Pierre, 2013). Due to this insider status I came to the process of thematic analysis with some knowledge about what might be found but endeavoured to remain open to new ideas and construction of knowledge. It was important to be open to the opinions, ideas, angles, multiple lenses and understanding of the topic under investigation that emerged. Reflexivity and the need to be open to the opinions of others, especially if it is contradictory to the values that I hold to be true (Bolshaw & Josephidou, 2019)were central to the approach at this stage. This is not an infallible system, but as Braun and Clarke (2022) suggest, this combined with my positionality is a strength.

In line with the Delphi technique, two forms of data analysis were used in this study: 1) reflexive thematic analysis (Braun and Clarke, 2019) for qualitative data generated, and 2) statistical analysis of scaled questions. With qualitative data, the aim was to code inductively, creating codes as the data were reviewed. However, I agree with Saldana (2021) that deductive (theory led) and inductive (data led) coding are dialectical, rather than mutually exclusive research techniques. The code list once created becomes refined, creating a deductive coding system for later analysis (Miles et al., 2020). More detail is provided in the methods section of this chapter.

4.3.6 Sampling Strategy

As part of the research design for Delphi, decisions that guide the expert panel makeup are typically outlined. This includes the selection process, inclusion and exclusion criteria, qualifications of experts, and rationale for selecting particular groups. Therefore, purposive sampling is used to determine the expert panel (Palinkas et al., 2015). Random sampling of members of the EC sector within the Republic of Ireland was considered as an approach for this study. It could answer the research question 'how should STEM education be implemented in ECEC in ROI?' and would access stakeholders' opinions, a priority for the researcher. However, this seemed like a premature step. EC STEM is a relatively new element of EC curricula and recent research suggests that educators in ROI report lack of training in this area (O'Neill et al., 2023), and are unsure about how to implement STEM with young children (Department of Education and Skills, 2020; O'Neill et al., 2023). It was important to me to include expertise from those who have a deep knowledge and understanding of EC STEM and EC education more generally, and for those making policy decisions to be exposed to this expertise as part of the research process. My hope was to influence future policy direction by combining these groups.

Samples in Delphi studies are purposive. It is recommended that qualifications of panel members, the size of the group and the balance of expertise should be critically appraised as part of critical design decisions in Delphi (Avella, 2016; Donohoe & Needham, 2009; Mullen, 2003; Powell, 2003). Purposive sampling is based on prior knowledge of a group of individuals and is therefore more likely to have the risk of bias (Hayes, 2001). Participants are selected based on predefined criteria to respond to the given research question. The reason for purposive sampling in a Delphi study is to match the research questions and objectives to the skills and knowledge of the experts, improving the rigour of the study and trustworthiness of the data and results (Campbell & Speldewinde, 2022).

Logically, to attain meaningful, legitimate, and quality Delphi results the panel's expertise must correspond with the research question (Avella, 2016). Panel selection, i.e. purposive sampling, is described as the most critical design decision in Delphi (Day & Bobeva, 2005; Donohoe & Needham, 2009b; Iqbal & Pipon-Young, 2009) as the success of a study is based on the on the combined expertise of expert panel (Powell, 2003). The method may be undermined if experts selected lack skills, qualifications, specialist knowledge, or profile in the field (Iqbal & Pipon-Young, 2009; Keeney et al., 2006). Broadly speaking, a varied panel is considered best in producing a reliable consensus. Perspectives of those who could provide alternative and minority viewpoints should be sought (Donohoe & Needham, 2009b; Linstone & Turoff, 2002) as well as including decision-makers who will use the outcomes, professional staff, and those with specific expertise (Hsu & Sandford, 2007; Skirton et al., 2013).

Further details about identification and recruitment of panel members are outlined in the next section.

4.4 Methods

This section details steps undertaken to prepare for, implement and distil data as part of a Delphi process. Participant recruitment, step-by-step Delphi procedures, details of data analysis (qualitative and quantitative) and ethical considerations are addressed.

4.4.1 Identification and Recruitment of Participants

A broad understanding of expertise is proposed for this study. While academic knowledge of STEM is useful, an interest in EC STEM, experience of practically applying EC STEM theory with young children, or a specialised knowledge of the Irish EC sector are also considered relevant expertise. Thus, the selection criteria that guided this study was as follows. Experts should

1. Understand the Irish EC context. **And /or**
2. Have experience supporting young children to engage with EC STEM**. And/ or**

3. Have academic expertise in early childhood science, technology, engineering, mathematics, or STEM more generally. This could include individuals from further and higher education with research experience. **And /or**
4. Be a potential contributor to the upcoming Literacy and Numeracy Policy, STEM Implementation plan or Aistear redevelopment i.e., have the ability to influence policy. **And /or**
5. Be a representative from a government department with responsibility for EC. This could include individuals from policy, inspection, or curricular development. **And /or**
6. Have expertise in supporting EC educators or students in ROI. This could include individuals from further and higher education, mentors, and those in local, regional, or national EC support services who provide PD opportunities. **And /or**
7. Have expertise in early childhood science, technology, engineering, mathematics, or STEM from other jurisdictions.

Potential experts were excluded if they did not meet *at least* one of the selection criteria listed. To generate a heterogeneous panel, individuals with a variety of positions including those whose expertise is situated in practice (educators and students), in theory and research positions (teacher educators, lecturers and researchers) in support roles (mentoring and professional development and training) and those with statutory or policy expertise (inspection, curriculum design, and other government organisations) were selected. Using Blieck et al.'s approach (2019), experts from a variety of levels with the EC macro-, meso-, and micro-systems were identified. In this study, the macrosystem referred to international expertise in EC STEM education, research, and academia; the mesosystem consisted of Irish policy including inspectorate, curriculum development, those likely to be consulted about or involved in STEM education policy and national training; the microsystem related to those working in or supporting educators working in EC education with an interest or expertise in STEM. While children could be considered experts, the time constraints and limitations of the study method would not allow for their participation. This is something that could and should be investigated later using methods suitable for young children.

The panel size was also considered as this could influence Delphi efficacy, legitimacy, and reliability. Clear guidelines about the optimum panel size, or what constitutes a *large* or *small* panel are lacking; but panels smaller than 10 and bigger than 1000 are rare (Akins et al., 2005; Avella, 2016; Fink-Hafner et al., 2019; Waggoner et al., 2016). Turoff (2002) advises that panels between 10 and 50 are suitable for most studies and considering the quantity of data generated by each panellist this figure is appropriate (Iqbal & Pippon-Young, 2009). The iterative nature of Delphi is a strength as it provides opportunity for researchers and panellists to improve the accuracy of the results (Hsu & Sandford, 2019). Equally, this increases the amount of time needed to complete the data collection processes. The volume of data generated by each panel member can be extensive, the workload increases for the researcher having implications for analysis, aggregation of data and completion of the study. As this is an independent study with a single researcher, this point was a particular concern. Consideration was given to the ideal size for *this* panel. In social studies the recommended panel size is at least six members and panels that exceed twelve members have not been shown to confer an increase in reliability (Rana et al., 2018). The median number of participants in health studies is higher at seventeen (Boulkedid et al., 2011). Balance of experts and their backgrounds must be maintained throughout the process to produce a valid group judgment (Donohoe & Needham, 2009) so the selection and balance of the panel is a key consideration in ensuring study completion is feasible.

The iterative nature of the Delphi method can also lead to participant fatigue and attrition (Boulkedid et al., 2011; Keeney et al., 2010; Skirton et al., 2013), mitigated by over recruiting at early stages in the process. Purposeful attrition management, for example, regular contact with panellists, using a personal and friendly approach, sending written reminders and individual thank-you messages, and being flexible with deadlines encourages experts to continue to engage with the process (Day & Bobeva, 2005; Fink-Hafner et al., 2019; Iqbal & Pipon-Young, 2009). In addition, careful planning and research design is recommended to combat participant fatigue, for example, numbers invited to participate are intended to allow for some level of attrition at each stage and still have a valid sample by the time the study ends. Considering this, over recruitment was deemed a useful tool to ensure a reasonable sample completed the process.

The twenty-six experts were contacted via email and invited to contribute to the study and a follow up email was sent two weeks later. This figure was reached by including a variety of expertise national and international and including additional numbers to allow for refusal and attrition throughout the process. Please see **Appendix 2** for invite details. Fifteen invitees responded favourably and participated in at least one round. One invited participant nominated a person from their organisation who they felt more fully met the 'expert' criteria. The final prospective participant list is outlined in **Table 4.2** along with details about the expertise of each panellist.

Fifteen participants indicated their interest in participation (white rows in **Table 4.2)** and were assigned identifiers. Of the remaining ten prospective participants, seven did not respond to the email invites (peach), and three stated they were not able to participate due to role restrictions or their organisation's policy (dark orange). Of the fifteen final participants, all completed at least two rounds.

	Role Descriptor	Level	Expertise	Rounds complete	Study Identifier
1	Educator	Micro	EC practitioner	3/3	E1
2			EC setting manager	2/3	E2
3			EC setting manager. STEM Doctoral candidate	3/3	E3
4			EC setting manager	**0/3**	-
5			EC practitioner with STEM MA	**0/3**	-
6	Academic	Micro/ Macro	EC STEM Lecturer /Researcher. STEM Doctoral candidate	3/3	A1
7			EC STEM Lecturer /Researcher	3/3	A2
8	Academic	Macro	EC STEM Lecturer /Researcher (North Hemisphere)	3/3	A3
9			EC STEM Lecturer /Researcher (North Hemisphere)	2/3	A4
10			EC STEM Lecturer /Researcher (South Hemisphere)	3/3	A5
11			EC STEM Lecturer /Researcher (North Hemisphere)	**0/3**	-
12			EC STEM Lecturer /Researcher (South Hemisphere)	**0/3**	-
13			EC STEM Lecturer /Researcher (South Hemisphere)	**0/3**	-
14			EC STEM Lecturer /Researcher (South Hemisphere)	**0/3**	-
15	Support	Meso	EC and PD expertise (ROI)	3/3	S1
16			EC, PD and STEM expertise (ROI)	3/3	S2
17			EC, PD and STEM expertise (ROI)	2/3	S3
18			EC, PD and STEM expertise (ROI)	3/3	S4
19	Policy	Meso	EC and PD expertise (ROI)	3/3	P1
20			EC and PD expertise (ROI)	3/3	P2
21			STEM and PD expertise (ROI)	3/3	P3
22			STEM expertise (ROI)	**0/3**	-
23			EC expertise (ROI)	**0/3**	-
24			STEM expertise (ROI)	**0/3**	-
25			EC expertise (ROI)	**0/3**	-
26			EC expertise (ROI)	**0/3**	-

Table 4.2. Final Expert Panel Invitee List

4.4.2 Stages of a Delphi Study

Heterogeneity in the Delphi process is inevitable (Rana et al., 2018) but there is general agreement that a Delphi study is considered to be methodologically sound if it: (1) clarifies the aim and purpose, (2) reports a reproducible method for recruiting panellists, (3) identifies the number of survey rounds a priori, (4) provides clear definition of consensus criteria and threshold value for consensus, and (5) reports criteria to drop items and when to end the study (Blieck et al., 2019; Diamond et al., 2014; Rana et al., 2018). Since the accuracy, and credibility of results of Delphi relies on rigour of the research process undertaken, the remainder of this chapter provides an overview of key considerations and steps taken to enhance rigour within the research design.

Beyond the four main characteristics of Delphi [anonymity, iteration, controlled feedback, and statistical aggregation], there are no universally accepted requirements. Literature on the subject reflects the uncertainty, confusion and contention that exists concerning the parameters of the Delphi technique (Boulkedid et al., 2011). There is no clearly prescribed length, format or consensus criteria, and several variations exist that diverge from the original (Fink-Hafner et al., 2019; Hasson & Keeney, 2011). Consequently, any Delphi study needs to consider and summarise design characteristics pertaining to the purpose of the study, number of rounds, participants and so on. To answer the research question 'how should STEM education be implemented in EC in ROI?' **Table 4.3** provides an overview of decisions made pertaining to Delphi design characteristics. Further details are discussed throughout the chapter.

Criteria	Possible Choice	Decision for this study
Purpose of the study	Exploration, testing, evaluation, problem solving	Problem solving
Number of rounds	Between two and ten	three
Participants/ sample	Homogenous or heterogeneous groups	heterogeneous
Mode of operation	Face to face, remote, hybrid	remote
Anonymity of the panel	Full or partial	full
Communication media	Paper and pen, facilitated, online (synchronous/ asynchronous), hybrid	online (asynchronous)
Concurrency of rounds	Sequential, real-time online conferencing	Sequential

Table 4.3. Taxonomy of Delphi design characteristics. Adapted from Day & Bobeva, 2000

Number and concurrency of rounds.

It is common for Delphi to be conducted over three rounds. If a clear literature base is available on which to establish a first-round questionnaire, a two-round Delphi is considered most suitable (Iqbal & Pippon-Young, 2009). Each round has a different goal as outlined in **Table 4.4.** According to Fink-Hafner et al. (2019) the round 1 questionnaire is qualitative and aims to identify topics relevant to the research problem discernible beyond the literature review. Rounds 2 and 3 are quantitative and standardised, using ranking scales to identify levels of consensus. The round 3 questionnaire is prepared based on round 2 results (ranking or validation of elements, exclusion of irrelevant elements) and enables panellists to evaluate outcomes and, if necessary, make further revisions. Panellists are then encouraged to use the statistics to inform their rating of topics in the next round to move toward group consensus (Rana et al., 2018).

Round	Structure of questionnaire	Goal/ focus of Questionnaire	Feedback between rounds
1	Open- ended questions	Ensure topics identified in lit review are relevant. Identify topics not captured in the first questionnaire but considered important by the panel	General feedback on areas of agreement
2	Likert scales with space for comments/ feedback	Beginning to achieve consensus. Adding topics previously overlooked Refinement of issues	Statistical results (mean, median, standard deviation) and an overview of comments
3	Likert scales with space for comments/ feedback	Achieve consensus and identify dissent	Statistical results (mean, median, standard deviation) and an overview of comments

Table 4.4 – Structure and goal of questionnaires in each round

Consensus definition

In a narrow sense, the number of rounds in a Delphi study is determined by the amount of time it takes to achieve consensus. Thus, the criterion used to define consensus dictates the length of the study and the number of rounds. In practice however, the criteria for stopping Delphi studies are often subjective. Stopping the Delphi procedure too soon may lead to results that are invalid or not meaningful, but a large number of rounds may cause participant fatigue with steep dropout rates (Keeney et al., 2006; Schmidt, 1997). While the number of phases vary from study to study, most change in panellists' responses is expected in the first one or two iterations (Linstone & Turoff, 2002). For this reason, I chose to aim for three rounds with the option of informal feedback should participants wish to make any further comments or outline any issues they may have with the final consensus. I decided a priori there would be a minimum of two and maximum of three questionnaire rounds, typical of most Delphi studies (Diamond et al., 2014; Rana et al., 2018; Waggoner et al., 2016). This was to ensure that respondent fatigue and attrition did not impact the results a common report a decreasing response rate is seen in each successive round (Hsu & Sandford, 2007; Keeney et al., 2010; Rüetschi & Olarte Salazar, 2020), and to curtail the amount of data generated to be analysed.

Consensus can be defined as opinion stability or the collective agreement among members of a group (Linstone & Turoff, 1975) and an *a priori* definition of consensus is recommended as a key component of rigour in Delphi studies (Diamond et al., 2014; von der Gracht, 2012). To achieve consensus, agreement among the expert panel must be measured, and a cut off rate agreed. It's widely accepted that consensus is based on statistical measures such as the percentage of ratings or the median value on a rating scale (Diamond et al., 2014; Jünger et al., 2017). Broadly speaking, for this study a >80% median threshold is used to define consensus. In this study, items are deemed to have reached:

1. 'strong consensus' if >90% of participants rated them in the top level of importance, OR >80% of participants rated using the top response AND 100% of participants used the top 2 levels of importance.
2. 'consensus' if >80% of participants rated them in the top level of importance, AND >90% in the top 2.
3. 'low consensus' if statements do not meet the above criteria for strong consensus or consensus.
4. 'consensus of disagreement' if >90% of participants rated them in the bottom level, OR if >80% of participants rated using the bottom response AND 100% of participants used the bottom 2 responses.

More details are provided about how this criterion was applied in the following sections of this chapter.

4.4.3 Stage One, Exploration

A review of numerous Delphi studies yields a common pattern in their structure which consist of three stages: exploration, distillation and utilisation (Day & Bobeva, 2005). **Figure 4.2** illustrates actions within each stage**.** The first stage, exploration, included tasks such as agreeing selection criteria for participants; selecting and inviting the expert panel; devising data collection and analysis tools; establishing an initial set of topics to be explored, and piloting tools. Considered a preparatory period, this stage also included the preparation of an extensive literature review outlined in chapters 2 and 3.

Establishing Questionnaire Topics - Pilot Questionnaire

Where an established research base is available, it is common for round-one of a Delphi study to be based on existing literature, especially when conducting education research (Beiderbeck et al., 2021; Green, 2014; Iqbal & Pippon-Young, 2009). As such, a combination of deductive and inductive approaches to data analysis is used throughout the study (see below for more detail on thematic analysis application across rounds). Round-one questionnaire was, therefore, based on themes that emerged from the literature reviewed in chapters 2 and 3. A pilot survey instrument was designed which included open questions and space for the expert panel to share opinions, clarify, critique, or add. See **Appendix 1** for details.

To ensure clear phrasing of topics and sub-topics, ensure that the language would be accessible and jargon- free, and to consider whether questions were leading or not, the phase one questionnaire was piloted with two Irish experts who both met the expert criteria outlined for this study. The first possessed significant knowledge about the EC sector in ROI, its history, policy, and the profile of EC educators and was chosen to reflect the Irish educational landscape, to consider multiple elements and issues that may arise. The second has significant EC STEM teaching and research experience and was chosen to review the questions with a STEM focus, and to reflect the queries arising around STEM discipline areas. The pilot document was distributed with 27 questions in seven sections – Consent, Participant Profile; Defining EC STEM; ECE and STEM; Essential EC STEM; STEM PD and Comments.

Recommendation	Questions affected	Sections affected
Merge	Four (merged to two)	N/A
Move to another section	Two	N/A
Clarify	Six	Section heading adapted
Remove	Six	N/A
Deemed unnecessary, repetitive	Two	N/A
Add	One	Clarify meaning of language in this questionnaire

Table 4.5. Changes to Questionnaire 1 based on Pilot Study.

Following feedback from these two experts, several changes were made. Where only one expert suggested a change, this was reviewed, and a decision made based on merit. If both experts made a recommendation it was enacted. Pilot participants recommended the use of more refined questions and the provision of examples when referring to STEM content areas or pedagogical methods. The final round one questionnaire was reduced from 27 to 17 questions based on feedback outlined in **Table 4.5**. The final version of the Round 1 questionnaire was structured into seven sections, under the following headings 1) Study overview and consent, 2) Participant Profile, 3) Defining EC STEM, 4) ECE and STEM, 5) Essential EC STEM, 6) STEM PD and 7) Overall comments. See **Appendix 3** for details.

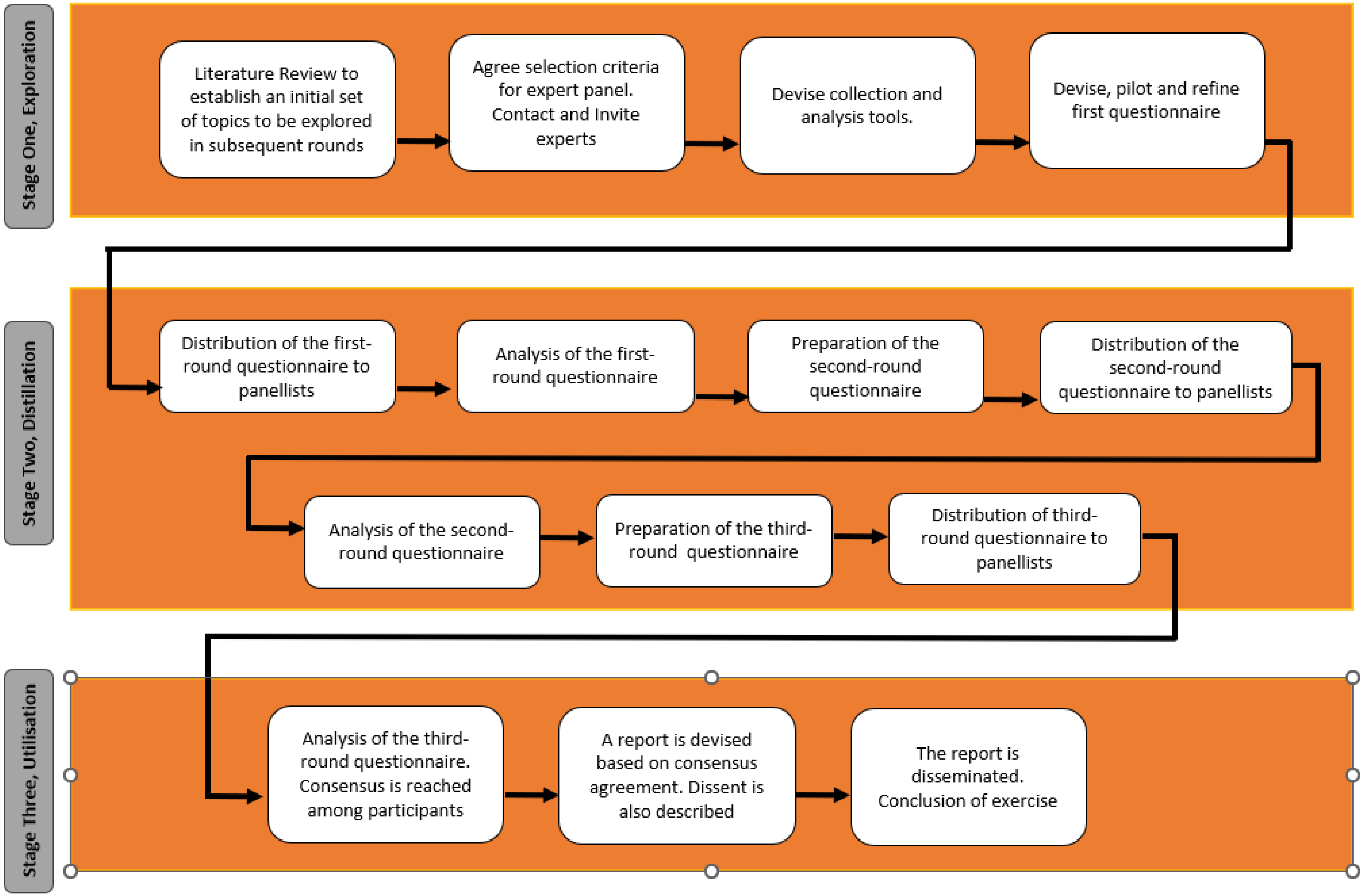


Figure 4.2. Key stages of a Delphi study

4.4.4 Stage Two, Distillation

This stage involves the distribution of questionnaires to the expert panel, followed by analysis and preparation of follow-up questionnaires and reports. Each round is discussed in turn. All communication was controlled through Qualtrics software which manages communication with the expert panel via email (providing access to plain language statement, gathering informed consent, sharing the online questionnaire, sending reminders, thanking participants for completing feedback), tracks completion rates (fully complete, partial, and yet to begin), enables basic qualitative analysis (mean, median, standard deviation), and allows data to be downloaded and analysed qualitatively.

Round 1 Questionnaire

Round 1 questionnaire was sent to 15 participants via Qualtrics in March 2023 (see **Appendix 3** for a copy of the round 1 questionnaire). Panellists received a private email, with an individualised link to protect anonymity and track responses via Qualtrics. A reminder email was sent after 2 weeks. All 15 experts completed the first questionnaire.

This round explored topics identified in the literature review and used open-ended questions to elicit expert opinion, ensure that chosen elements were relevant, identify any emerging issues with language, and uncover topics that were not captured in the first questionnaire. Data were reviewed as they were returned, read, and re-read before beginning a process of inductive coding. The questionnaire contained open-ended questions only, and therefore reflective inductive analysis was employed using Braun and Clarke's thematic analysis framework (Braun & Clarke, 2020). See **Appendix 10** for a copy of sample codes, descriptors, and typical and atypical examples.

This data was used to create statements for round two using both typical and atypical comments to generate statements. In some instances, this meant that statements presented to the expert panel were contradictory. An example of how themes and comments were used to create statements for the round 2 questionnaire is outlined in **Figure 4.3.** To see further examples and for a list of all statements included in round 2 questionnaire, see **Appendix 4**.

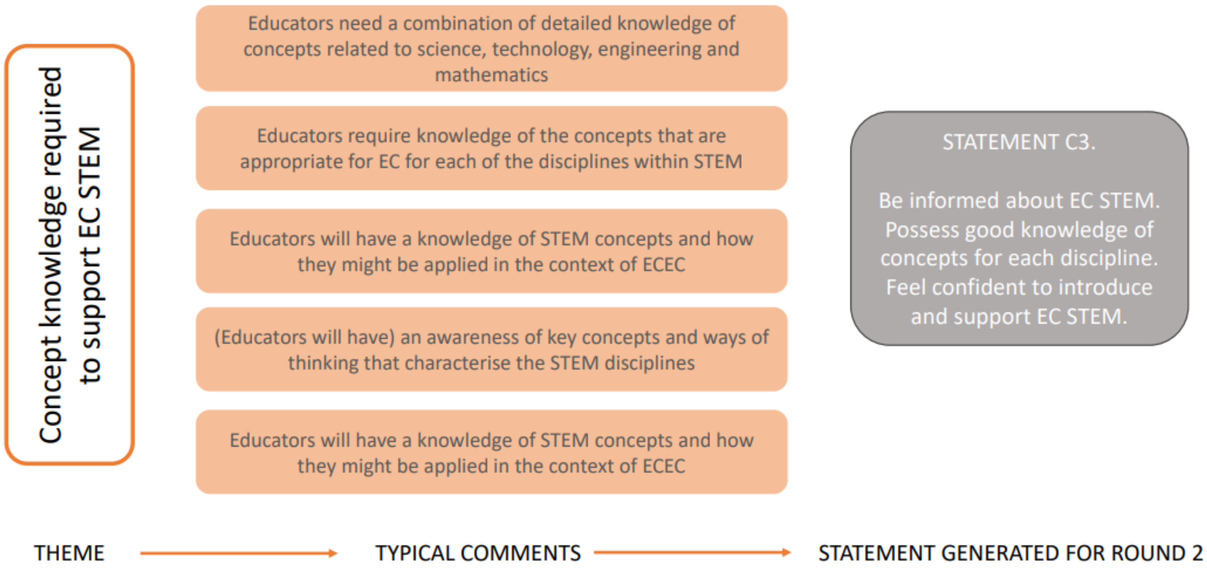


Figure 4.3. The creation of statements for Round 2 example

Where dissatisfaction with language was voiced, feedback was also taken on board. For example, a quarter of the expert panel (4/16, 25%) expressed concerns about the use of the term ‘monitored’ when referring to EC educators’ professional development. This language was changed in round 2 questionnaire from “How should EC professionals be monitored and supported once early childhood STEM professional development is complete?” to “How should EC professionals be supported once early childhood STEM professional development is complete?" to reflect this feedback.

Round 2 Questionnaire

Proceeding to round 2, the panel received a new questionnaire and instructions for its completion. See **Appendix 4** for a copy of the round 2 questionnaire. The second-round questionnaire was structured into six sections, under the following headings, 1) Instructions and consent, 2) Defining EC STEM, 3) Early childhood education and STEM, 4) EC STEM knowledge, pedagogy, and dispositions, 5) STEM Support and Professional development and, 6) overall comments and feedback. The expert panel were presented with 120 statements and asked to rate their level of agreement from 1 (not important) to 5 (essential). Likert-scales were used for all questions in sections 2 to 5, and an opportunity to provide open ended feedback, critique or suggestions was included at the end of each of these sections.

The questionnaire was distributed to 16 panel members in May 2023, with follow up emails sent after 3 weeks. In total, 13 responses were received in round 2. The return rate was monitored and deemed an acceptable size as it met the *a priori* quorum of >80%. Responses were quickly checked to ensure they were completed in line with instructions before analysis of data began. Round two analysis was carried out in two ways. Firstly, Likert-scale questions, data were analysed via Qualtrics to find the mean, median, standard deviation and descriptive statistics for each statement. In terms of consensus, raw scores from each statement were reviewed and ordered from largest to smallest by median, as this was deemed the most appropriate measure for ordinal data such as these (as per Pearson et al., 2014). The mean was also calculated to provide a more precise indicator of central tendency, as was standard deviation. Frequency distribution and descriptive statistics were gathered for each statement and analysed to assess whether strong consensus, consensus or consensus of disagreement was evident. Using consensus criteria (see **Appendix 13** for details), 38 statements achieved high consensus, 32 achieved consensus and 50 achieved no consensus. No statement achieved a statement of disagreement. For overall results in round 2, see **Appendix 5**.

Secondly, open-ended questions, statements, comments, and critique from each section were centralised in an excel spreadsheet using Qualtrics. These were treated somewhat differently:

- **Comments.** Generally, comments provided context for a panellist's choice. These comments were cleaned to remove any typos, identifying information and extraneous words. If multiple panellists gave feedback along the same lines, these were collated. Comments were presented to the expert panel as part of the round 2 report.
- **Critique.** In some instances, panellists strongly disagreed with terminology, or the implications of the questions being posed. For example, asking questions about centralised training suggested a neoliberal approach to further education which some experts opposed. One panellist stated that they opted out of answering section 4 'stem support and professional development' for this reason. This was shared with the panel.
- **Suggestions.** If suggestions did not contradict an established and strong group consensus, explicit suggestions to change statements were adopted for round 3.

Based on explicit feedback from the expert panel, changes were made to three statements within the 'skills, knowledge and pedagogy' section of the questionnaire. These were:

1. Statement C9 was changed from "*Understanding of technology and a high level of digital literacy"* to "*Knowledge and experience of using digital technologies creatively."*
2. Statement C11 was changed from "*How to identify if wellbeing, identity and belonging, communication is compromised due to a focus on STEM" to "Knowledge and awareness to foster approaches to STEM which ensure children's wellbeing, identity and belonging and communication are encouraged and supported within STEM learning experiences."*
3. Statement C36 was changed from "*Focused on fun"* to "*A willingness to be playful".*

Round 3 Questionnaire

Proceeding to round 3, the panel received an updated version of the questionnaire *and* a personalised report. Controlled feedback in the Delphi process is designed to reduce the effect of noise or the 'communication which occurs in a group process which both distorts the data and deals with group and/or individual interests rather than focusing on problem solving' (Hsu & Sandford, 2019, p. 2). However, Dalkey and Helmer (1963) the designers of the original Delphi acknowledge that some 'leading' by the researchers is inevitable resulting from the selection of the information supplied to the panel. The reports outlined statistical data for each statement including frequency data, the mean, median, standard deviation, lowest rating attributed, number of responses and the expert's personal rating for the statement in the last round. Comments from panellists were also included in each section, including where dissent was expressed. Please see **Appendix 5** for a sample report.

The third-round questionnaire was structured into six sections, as per round 2. The expert panel were presented with statements and asked to rate their level of agreement from 1 (not important) to 5 (essential) and an opportunity to provide open ended feedback, critique or suggestions was included at the end of each of these sections. This time, however, they were also provided with a report that outlined their response, *and* statistical data and comments pertaining to the answers of the remaining panel members. The questionnaire and personalised reports were distributed to 15 panel members in September 2023 (including those who completed the survey in round 1 but had not responded in round 2). Once again, these were sent via Qualtrics with personalised links so that feedback could be tracked and follow up emails sent after 2 weeks. In total, 13 responses were received. The return rate was monitored and deemed an acceptable size as it met the *a priori* quorum of >80% of the original figure. It is worth noting that 13 experts completed round 2 and round 3. However, these were not the same 13 experts. Please see **Appendix 7** for an overview of the number of rounds completed by each panellist.

4.4.5 Stage 3, Utilisation

This stage sees the end of the Delphi cycle. Once again, returned questionnaires are reviewed and statement responses ordered from largest to smallest by median. The mean, standard deviation, frequency distribution and descriptive statistics were gathered for each statement and analysed to assess whether strong consensus, consensus or consensus of disagreement was evident. Using consensus criteria (see Appendix 13 for details), 35 statements achieved strong consensus, 22 achieved consensus and 63 achieved no consensus. No statement achieved a statement of disagreement. For overall statistical results in round 3, see **Appendix 9**. Once data was analysed a final report was issued to the expert panel, which clearly outlines consensus and dissent. See **Appendix 9** for a sample final report.

At the utilisation stage, a number of additional analyses were carried out including:

1. A review of open-ended data collected during round 3 to identify any additional themes/ sub themes that emerged from comments, suggestions, or critique. These were compared to comments, suggestions or critiqued from round 2 and a final list of themes and subthemes was created pertaining to open-ended responses.
2. A review of response stability across rounds 2 and 3. A statement with a higher stability rate across rounds is considered to be more reliable. Please see **Appendix 10** for a sample report identifying response stability across rounds.
3. A reflexive thematic analysis of the results of the final round. Within this, patterns in level of consensus across statements or dissent are identified. This interpretative process enables the making of meaning by examining the subjective responses of multiple stakeholders. Consensus and dissent are identified to *tell the stories* Braun & Clarke, 2019) of EC STEM in the Republic of Ireland. Meanings are ascribed using the researcher's personal and professional lens and consider all data collected over the course of the Delphi procedure.

4. Dissent analysis. Stakeholder-group analysis, outlier analysis and bipolarity analysis were carried out to identify any additional patterns and provide further insights into the data.

4.5 Data Analysis

Due to the structure of the Delphi process and the multiple stages involved, it is not easy to describe the analysis process in a clear-cut way. Both inductive and deductive approaches were used throughout the research. In some instances, approaches were used singly and other times in combination. In line with reflexive thematic analysis Braun et al., (2019) state that this type of approach is typical as coding is flexible and organic and evolves over time. For the benefit of the reader and for the sake of clarity, **Table 4.6** lays out the analytical steps and processes undertaken during the Delphi process and identifies the underlying approaches that informed them. For the most part, the stage of the Delphi process dictates the type of data being generated, and therefore, the type of analysis being carried out.

For example, in the round 1 questionnaire only open-ended questions were posed and therefore, thematic analysis was used to identify codes and themes. However, the first questionnaire was structured using headings identified in the literature and statements developed were categorised under these headings. As such, inductive and deductive approaches to analysis were carried out. As per Byrne (2022), both semantic and latent coding were utilised, and no attempt was made to prioritise one over the other. Data could therefore be coded more than once i.e. the latent meaning as interpreted by the researcher *and* the semantic meaning communicated by the respondent.

Thematic analysis used in the study was based on Braun and Clarke's thematic analysis framework (Clarke & Braun, 2019, 2022) which outlines 6 steps identifying themes in qualitative data. **Table 4.6** lists these phases and illustrates how codes and themes are generated and refined. A 15-point checklist (Braun & Clarke, 2022) was used to administer quality controls in relation to thematic analysis. These cover all stages of the data collection and analysis process from transcription to production of the final report.

	Phase	Description
1	Familiarization with data:	Reading and re-reading the data, noting down initial ideas
2	Generating initial codes:	Coding features of the data in a systematic fashion across the entire data set, collating data relevant to each code.Identification of latent codes driven by the questionnaire topics and initial semantic codes
3	Search for themes:	Collating codes into potential themes, gathering all data relevant to each potential theme. Some quotes coded twice - latent and semantic
4	Review themes	Check themes work in relation to the coded extracts (Level 1) and the entire data set (Level 2), generate a thematic 'map' of the analysis.
5	Define and name themes:	Ongoing analysis to refine the specifics of each theme, and the overall story the analysis tells, generating clear definitions and names for each theme. Identify key quotations to represent each theme.
6	Produce report	Select compelling extract examples, final analysis of selected extracts, relating back of the analysis to the research question and literature. Mindful of subjective interpretivist approach

Table 4.6. Phases of Thematic analysis. Adapted from Braun and Clarke (2006)

When seeking initial codes at first a simple 'summary of findings' are identified. For example, when considering questions pertaining to the definition of STEM the qualitative data identifies which *version* of the definition is preferred. Only after this is established can I begin to reflect on and understand this consensus, taking on board 1) comments from the group, 2) my experience and understanding on EC and EC STEM, 3) the possible meanings. As Braun and Clarke note ' viewing these as always context-bound, positioned and situated, and qualitative data analysis is about telling stories', about interpreting, and creating, not discovering, and finding the truth that is either out there and findable from, or buried deep within, the data (Braun & Clarke, 2019, p. 5). What is stressed is the need to move beyond the domain summaries organised around a shared topic and identify shared meanings that capture the diversity of meaning in relation to a topic (Braun & Clarke, 2019). The importance of recurrence/ frequency is acknowledged in this process but that meaning, and meaningfulness is the central criteria in the RTA coding process (Byrne, 2022).

The possibility of moulding information is another potential challenge. Yousuf (2019) outlines how researchers can impose their views and preconceptions upon the expert panel by over structuring the Delphi questionnaire and not allowing for contribution of others throughout the study. The Delphi may fail if poor procedures are used to summarise and present the group response and/or if interpretations of the evaluation scales are mismanaged (Linstone & Turoff, 1975). Acknowledging the interpretivist orientation adopted in this study, it is necessary to resist the claim that I or the research is neutral (Lather, 2006). However, I aim to regularly reflect on how my position and knowledge may unduly influence this study. Reflexivity is commonly viewed as the process of a 'continual internal dialogue and critical self-evaluation of researcher's positionality as well as active acknowledgement and explicit recognition that this position may affect the research process and outcome' (Berger, 2015, p. 220). It is used to enhance a study's rigour, monitor ethics, and highlight conflict between the ongoing involvement and detachment of the researcher and the researcher (Bradbury-Jones, 2007; Pillow, 2003). I agree that personal accountability is required within a research journey. Framing of questions, approaches and interpretation and analysis requires systematic self-critical inquiry and thoughtful review (Carr, 2000; Stenhouse, 1981). Berger (2015) maintains that reflexivity can support qualitative researchers to understand the role of the self in the creation of knowledge, focus on self-knowledge and sensitivities, and monitor the impact of their biases, beliefs, and personal experiences on their research.

4.6 Ethical Considerations

Issues of ethics and participant safety are paramount in empirical research. The desire to advance personal or societal understanding of a topic must be balanced with the rights and wellbeing of participants. While all research inherently comes with some elements of risk (Williamson et al., 2021) research ethics and integrity consider how to respect participants and provide a duty of care (Dove & Chatfield, 2023).

Consent is one necessary foundation for ethical research and the informed consent process must meet acceptable standards (Davies, 2022). It requires essential elements of voluntarism [to judge and choose freely in the absence of coercion]; information disclosure, or provision of details to enable participants make an informed, rational, and logical decision; and finally, the presence of decision-making capacity [the ability to understand and appreciate the nature and consequences of participation] (Gupta, 2013). As such, a plain language statement was devised and shared with potential participants (see **Appendix 8**). Participants were given the opportunity to discuss any queries arising from the plain language statement over the phone or by email with the researcher.

Survey Tool	Input	Approach to analysing source input	Outputs
Pilot Questionnaire	Literature Review	**Deductive and semantic**- search for common overarching themes in the literature **Inductive and latent** - Search for literature that reflects the Irish Context using my expert lens	**Round 1 Delphi questionnaire** 34 Pilot questions under 6 headings 1. Participant profile 2. Defining EC STEM 3. Early Childhood Education and STEM 4. Essential EC STEM Elements 5. Professional Development Sector-wide Supports
Round 1 Delphi Questionnaire	Literature review Feedback Pilot Questionnaire	**Deductive**- statistical data is reviewed to look for mean, median and so on. **Inductive** - panellist comments, implied meaning and patterns are identified to group and combine comments for reports	**Round 2 Delphi questionnaire** 120 statements under 4 headings 1. defining EC STEM 2. Early Childhood Education and STEM 3. STEM Knowledge, Pedagogy and Dispositions Sector-wide Support and Professional Development
Round 2 Delphi Questionnaire	16 Round 1 responses	**Deductive**- statistical data is reviewed to look for mean, median and so on. **Inductive** - panellist comments, implied meaning and patterns are identified to group and combine comments for reports	**Individual Panellist Reports (15)** Including 1) Statistical data for each statement 2) Panellist comments and suggestions
Round 3 Delphi Questionnaire	13 round 2 responses	**Deductive**- statistical data is reviewed to look for mean, median and so on. **Inductive** - panellist comments, implied meaning and patterns are identified to group and combine comments for reports	**Individual Panellist Reports (15)** Including 1) Statistical data for each statement 2) Panellist comments and suggestions
Final report for experts	13 round 3 responses	**Deductive**- statistical data is reviewed to look for mean, median and so on. **Inductive** - panellist comments, implied meaning and patterns are identified to group and combine comments for reports	**Final Panellist Report** Including 1) Statistical data for each statement 2) Panellist comments and suggestions
Final results	All data collected	**Deductive** - using headings from literature review to structure **Inductive -** looking for meanings and explanations across consensus dissent and comments	Study Findings

Table 4.7- an overview of analytical approaches across the Delphi process

Obtaining informed consent is not a once-off incident but an iterative process (Gupta, 2013). Re-consent is an important ethical aspect of the Delphi approach. In this study consent was obtained repeatedly from the panel who were asked to re-consent each time they completed a questionnaire (rounds 1, 2 and 3). This maintains open lines of communication enabling participants to share concerns or ask questions. This process was managed formally via Qualtrics, and informally via email or phone.

Bertram et al. warn that 'researchers must be aware that the research process may put pressure on or lead to potentially harmful consequences for participants' (Bertram et al., 2016, p. vii). I recognise that as the researcher, I am in a position of power and have been mindful of ensuring that participants understand they can withdraw from the study, choose not to respond to sections of the questionnaire, and have any personal identifiable features, or those of their organisations, changed in order to minimize the potential that they could be identified. The fact that data is collected remotely physically removes me from the process and is a small way may address some of the potential power imbalance.

4.7 Conclusion

The Delphi framework is designed to gain consensus from a group of experts on a topic where little is known. The process can counter many of the issues outlined in this paper by overcoming issue with fragmentation or siloed working typical in ECEC in Ireland; ensuring that clear actions in relation to several aspects of STEM education policy will be addressed; have a clear vision for the way forward; meaningfully consult with the sector. The Delphi technique is well suited as a method for consensus-building (Hsu & Sandford, 2019). The government has acknowledged that the range of supports that exist in primary and post primary to STEM are absent in ECEC (Department of Education and Skills, 2020b) and yet a clear consensus on how this is to be addressed is absent from the extensive range of policy documents being published by the Irish State. Finally, if a consensus is reached by using the Delphi method, this information has the potential to influence the development of future ECEC documents such as the national curriculum framework, literacy and numeracy strategy and workforce development plan.

Chapter 5

Findings and Discussion

Chapter 5 Findings and Discussion

5. 1 Introduction

This chapter details the findings of the Delphi process, and positions results in line with current literature. First, an overview of the Delphi process, including the number of statements to reach consensus per round and panel organisation per round, is provided. Second, a detailed explanation of findings at the end of the three-round Delphi process are outlined using the Delphi questionnaire headings to structure the discussion: defining STEM; STEM and early childhood education; essential STEM knowledge, pedagogy, and dispositions; and support for EC STEM. Each section includes detail about consensus reached, situates these findings within current literature and offers implications for policy and practice. Thirdly, dissent between expert groups within the panel is outlined. While consensus was reached based on input from the entire panel, some interesting findings emerged when the expert panel were divided by role (i.e. educator, lecturer, researcher, support, or policy role) and responses compared. Where relevant, dissent is linked to pertinent literature and implications for policy and practice identified. Finally, the chapter concludes by highlighting overall implications for STEM policy in ROI.

5.2 Findings Overview

This section provides an overview of results from each round of the Delphi process. Results are presented in relation to three Delphi rounds including response rates, statement generation and change, and consensus rates. An overview is provided in **Figure 5.1.**

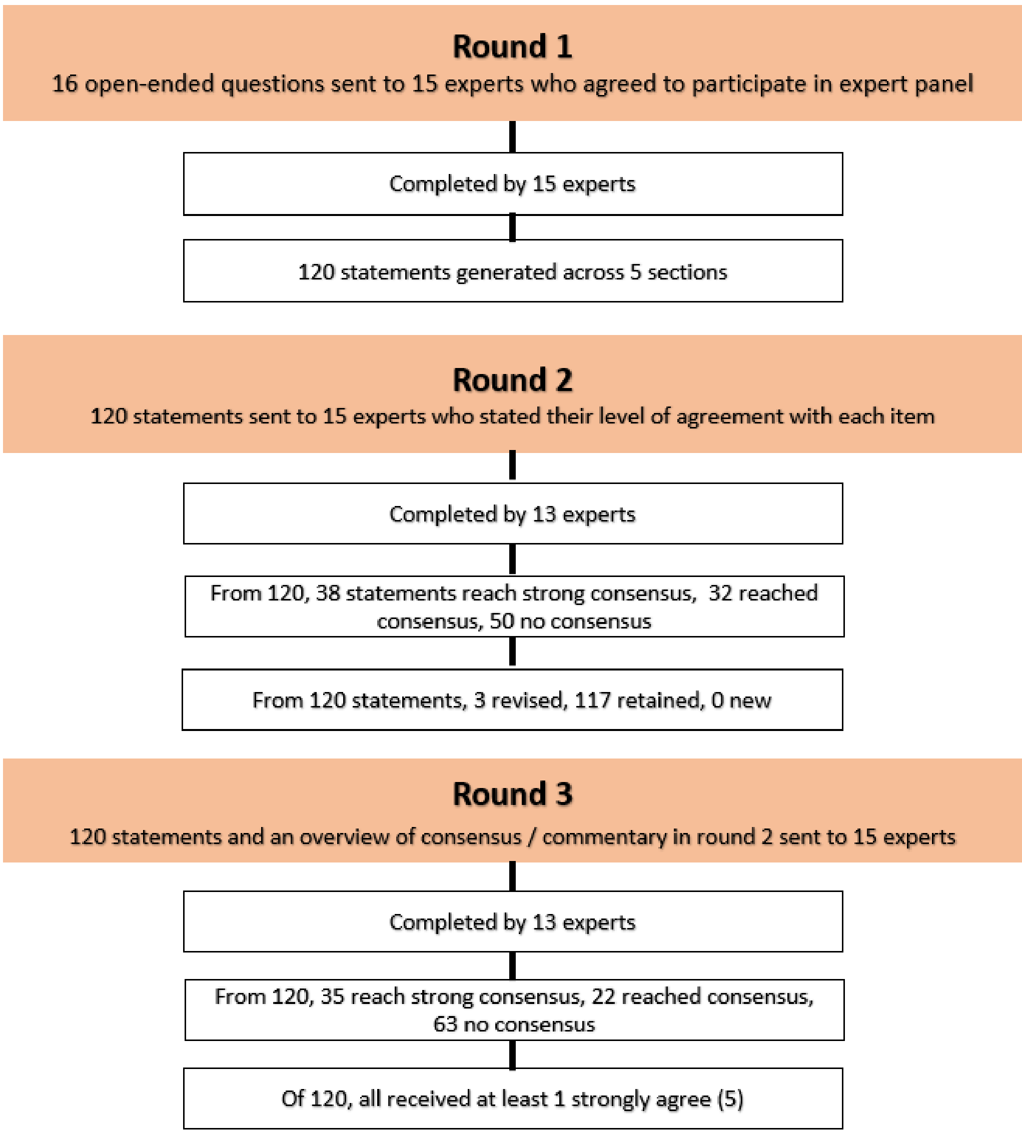


Figure 5.1 Overview of Delphi data collection per round

Questionnaire Section	Semantic Themes	Sub-themes	Inductive/ latent themes appearing across sections
Defining EC STEM	Creativity; *Role of the adult;* Subject inclusion	1. Integration 2. Equitable Inclusion of STEM 3. Negative view of planned activity 4. Positive view of planned activity 5. Favoured the Arts 6. Creativity in EC 7. Language of STEM	Respect for EC tradition Fear of schoolification Following children's interests Reflecting community and family Adult as partner Distrust of Government EC STEM not essential What is appropriate/ inappropriate for young children Intentionality of the adult Move away from what is at the core of EC Frustration at lack of support or resources provided for EC Play Holistic learning
Early Childhood Education and STEM	Meaningful; *Role of the adult;* Curriculum approaches	1. Inquiry-based activity 2. Following interests 3. Reflecting community and family 4. Negative view of planned activity 5. Align with Aistear 6. Lack of curriculum knowledge	
Role of the professional	Structure of adult input; STEM Knowledge and Understanding; Technology use.	1. Appropriate adult input 2. Directive adult input 3. Broad and deep understanding of STEM 4. identifying STEM in everyday 5. Active use of technology 6. Align with policy agendas 7. Reflecting children's lives [digital lives]	
Professional development and supports	*Role of the adult;* Distrust and low expectations	1. Knowledge 2. Pedagogy 3. Dispositions 4. Attitudes 5. Appropriate use of technology	
Effective methods of organising / facilitating EC STEM PD	Structures; Working in partnership	1. Type of support 2. Resources 3. Link to policy 4. Consultation 5. Leadership	
Final comments	*Role of the adult;* Respect for EC	1. Disability and inclusion 2. Issues in the sector 3. Implementation support 4. Bottom up practices 5. STEM knowledge and skills 6. Child-led practice	

Table 5.1 Overview of themes and subthemes

Following the RTA of the data generated as part of the Delphi procedure, a number of themes and subthemes were identified within the data. Due to the combined deductive/inductive approaches taken to data analysis, these themes were structured using the Delphi questionnaire section headings. Twelve semantic themes and a number of sub-themes were identified and organised using questionnaire headings. An overview of this information is provided in **Table 5.1**, demonstrating how themes and sub-themes appeared across the questionnaire headings. Latent themes identified are also outlined in the final column of this table. These themes appeared across all sections of the questionnaire. Further details and a mapping table relating to these themes are outlined in **Appendix 13.**

In round 1, the panel were asked several questions relating to their role, STEM experience and facilitation of STEM PD or ITE. See **Appendix 3** for a copy of questionnaire 1. Experts were chosen for particular skill sets or experience, but responses show that experts were competent in many areas. For example, some EC educators also had research and professional development facilitation experience. Further details about self-reported expertise, assigned identifiers and number of rounds completed by each panel member are provided in **Appendix 7.** For reporting purposes, experts were organised into 4 categories based on their roles.

Role title	Role Descriptor	No. of experts	Identifiers
Educator	Working directly with children in some capacity	3	E1, E2, E3
Support	Working in a support, mentoring, or training role	4	S1, S2, S3, S4
Academic	Working in research or lecturing in tertiary education	5	A1, A2, A3, A4, A5
Policy	Working in inspection, curriculum development or policy	3	P1, P2, P3

Table 5.2: an overview of expert profiles and role descriptors

While some Delphi procedures remove statements once a named level of consensus is reached, in this study all statements remained in contention until the end of the third and final round. This allowed panellists to view and consider the opinions and comments from the remainder of the panel. As **Table 5.1** illustrates there was significant change in consensus from round to round. Of note, far fewer statements reached consensus by the end of the Delphi process. **Figure 5.2** below illustrates this.

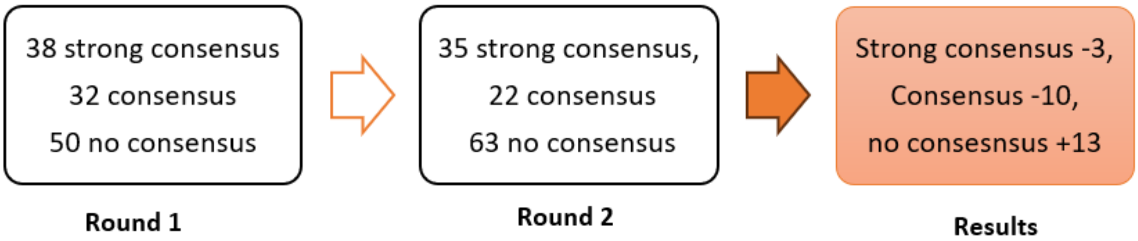


Figure 5.2. Overview of consensus change by round.

Across rounds, very few statements (3) were revised, none of the statements reached consensus of disagreement, and all statements in all rounds received at least one level five rating (extremely important). Consensus changed from round to round and response stability varied across the 120 statements. However, there were some statements where opinions changed considerably from round to round. Please see **Appendix 9** for an overview of response stability for the 120 statements. Dissent analysis is considered an important element of Delphi processes and can be neglected (Beiderbeck et al., 2021).

Absence of dissent analysis is considered a design flaw (Shrier, 2021). Therefore, dissent is discussed in greater detail at the end of this chapter.

5.3 Findings by Delphi Section.

The findings from the complete Delphi procedure are detailed in this section. Findings are presented using the five main Delphi questionnaire headings (defining STEM; STEM and ECE; Essential STEM Knowledge, Pedagogy and Dispositions; Supports for EC STEM; Final comments) and are structured as follows:

1) *Consensus.* Tables present all statements that secured strong consensus or consensus in the final round. For details of how consensus is defined see the criteria outlined in **Appendix 13.** Consensus is illustrated / supported by opened-ended comments from panellists to illustrate key points and offer interpretation.
2) *Literature.* An overview of supporting literature/ gaps in literature identified offering connections to and deviation from the existing literature.
3) *Key messages*. Identification of key messages and impact this information may have on policy and practice.

5.3.1 Section A. EC STEM Definition

Consensus

Level of consensus reached	Essential elements of an Early Childhood STEM definition
Strong consensus	Science Technology Engineering and Math
Strong consensus	Play
Strong consensus	Curiosity
Strong consensus	Creativity, Imagination
Consensus	Critical Thinking

Table 5.3 Consensus on essential elements of an Early Childhood STEM definition

Items in this section pertain to how STEM should be defined within early childhood. Views of the expert panel suggest that the four constituent disciplines of Science, Technology, Engineering and Mathematics are key, along with a strong focus on play and exploration common in many EC philosophies and curricular approaches**.**

Level of consensus reached	Integration of subjects/ disciplines in Early Childhood STEM.
Strong consensus	STEM disciplines naturally coexist and overlap in EC settings. One or more STEM disciplines can arise during play and/or routine activities leading to integration.
Consensus	EC STEM is any experience, activity, routine, or discussion involving a STEM discipline (**either** science, technology, engineering, math or a combination of these disciplines)
Consensus	The use of the project approach or long-term investigations supports integration of STEM subjects over time.

Table 5.4 Consensus on integration of subjects/ disciplines in Early Childhood STEM.

There is agreement that the holistic nature of EC pedagogy and play-based curricula lend themselves well to the integration of STEM subjects in ECE. This, once again, highlights the importance of play and everyday nature of STEM experiences for young children. Open-ended comments indicate that caution is advised in the provision of separate, subject-based activities or experiences. It can be inferred from multiple open-ended comments that separate and subject-based STEM experiences are conflated with prescriptive and adult-led approaches deemed inappropriate in an early childhood setting.

> *'Teaching STEM subjects in isolation can sometimes lead to a more directive teaching style, potentially limiting the scope of exploration and creativity. However, when integrated effectively with open-ended, play-based learning experiences, children can develop critical thinking skills and a deeper understanding of the interconnected nature of STEM disciplines.' (S3)*

Consensus in this section indicates that EC STEM can be defined loosely, applicable to any activity, routine or discussion involving an individual STEM discipline or combination of these disciplines. The next section aims to place these agreements within the existing literature.

There was some level of dissent in this section. For example, all but one panellist rated 'language of STEM' as important (46.7%) or extremely important (46.7%) and while this demonstrates an increase in ratings from round 2, it was still insufficient to reach consensus. Two experts commented specifically on this statement in round 3 and both were very insistent about its importance:

> *Using the Language of STEM can support language development as well as an understanding of STEM concepts. Integrating language skills within STEM activities helps children articulate their observations, ideas, and findings'. (S3)*

One expert made the point that correct terminology, or definitions are not important to young children's experiences of STEM, stating that:

> *'…it is the experiences and how they make the child feel that are important. They are not interested in policies or having the right terminology. They want to learn about the world through play and hands on experiences. They don't care if it is called STEM or STEAM or called something else, they just want to play! (P2)*

It should be noted that there was some dissent in this section from the academic cohort who were unhappy that more specificity had not been agreed in relation to maths content. For example:

> *I still disagree that teaching STEM subjects separately can lead to more directive pedagogies - I think it is perfectly possible to teach early mathematics through emergent play-based approaches, for example. Given the evidence of current limitations in ECE STEM teaching, I think some support for planning of STEM activities is both necessary and useful. I agree that prescriptive approaches should be avoided - and - in any case, adaptive interpretation of approaches is a fact. (A5)*

Supporting Literature

Contemporary literature outlines variation in the conceptualisation and definition of the purpose, structure, and goals of STEM education (Jamil et al., 2018; Palmér, 2019). In a relatively new and ill-defined field, multiple stakeholders, agendas, and priorities lead to competing theories and approaches to STEM education (Barkatsas et al., 2018; Siekmann & Korbel, 2016) and the question of what constitutes STEM remains an issue for curriculum developers and educators (Fraser et al., 2018; Johnson et al., 2021; McComas & Burgin, 2020; State Education Agency Directors of Arts Education, 2020). Therefore, the need to agree core elements of STEM practice that are useful and appropriate in EC is paramount to finding a roadmap for EC STEM practice in ROI.

Hasanah (2020) identifies four ways to frame definitions of STEM; as a discipline, as instruction, as a field and as a career. Agreements reached by the expert panel position EC STEM as a discipline and as instruction, both of which can be considered as part of the definition. Further details about how the expert panel agreements connect with Hasanah's frame are outlined in **Table 5.5.** The definition of EC STEM agreed by the panel refers not only to a wide range of discipline content knowledge but also implies a certain pedagogical approach. Mirroring findings from Campbell and Speldewinde (2022) the acronym 'STEM' was found to include all or some of its constituent disciplines and refers to the development of inquiry skills and thinking capabilities.

This aligns with the integrative approach to teaching and learning often associated with STEM education (Belbase et al., 2021; Wan et al., 2021; Zendler et al., 2018). As part of this approach, real-world scenarios and authentic problems that are meaningful to the children are used to engage with STEM. These points are crucial when considering EC STEM. Rather than a focus on content knowledge or the accumulation of facts in relation to science, technology, engineering and maths, the expert panel propose that the pedagogical approach and focus on wider range of intellectual and/ thinking skills should frame STEM in EC e.g. exploration, investigation, critical thinking; and the use of children's interests and real-world experiences imply a child-led and active role for children. This aligns with the principles of Aistear, Ireland's early childhood curriculum framework (NCCA, 2009). As such, the definition and approach presented by the panel would work well within the current curriculum and policy environment in ROI.

STEM Frame (Hasanah, 2020)	**Questions re EC STEM**	**Consensus from the Expert Panel**
STEM as a Discipline. Related to discipline-specific content/ Relates to one or more discipline area/ A minimum number of disciplines will be integrated.	What, if any, STEM discipline/s should be included in EC? Should these disciplines be integrated or stand-alone?	● EC STEM is defined as any discipline-specific experience, activity, routine, or discussion. ● It can include any of the 4 individual disciplines of science, technology, engineering, math, or a combination of any of these disciplines. ● There is an understanding that integration of STEM disciplines often occurs during play or routines in EC settings. ● The expert panel caution that an excessive focus on single discipline areas could lead to prescriptive / adult led approaches contrary to EC philosophy and pedagogy.
STEM as Instruction. STEM as an approach to teaching/ Active, student-centred learning/ Inquiry, reasoning, digital learning, cooperative learning, hands on, 21st century skills, application to real life	What approach/ pedagogy to support EC STEM is suitable in EC? What skills/ knowledge do we expect children to learn?	● Active learning, play and exploration are key to supporting EC STEM. ● The use of the project approach or long-term investigations supports integration of STEM subjects over time. ● Framing approaches to include support for children's curiosity, creativity, and imagination are crucial. ● Support for children's critical thinking should be considered as part of the approach/ instruction. ● Application to real life and to children's ongoing/ emerging interests are essential.

Table 5.5 Expert panel consensus linked to Hasanah, 2020

The limited literature on EC STEM in play-based learning environments supports the idea that young children experience STEM in an integrated way as part of their everyday lives (Campbell & Speldewinde, 2022). Similarly, the panel expressed the opinion that the integration of STEM disciplines often occurs during play or routines in EC settings. However, panellists commented negatively about the provision of separate, subject-specific experiences or activities. For example, when asked about equitable inclusion of each subject across the academic year this was deemed prescriptive and an 'additional and unwarranted complicating factor' that could deviate from the approach of following children's interests and ideas. In its place, the use of long-term investigations or projects was suggested to encourage integration of subjects over time and support the essential elements of play, curiosity, creativity, imagination, and critical thinking identified in the EC STEM definition.

The panel agreed that 'the arts' is not an essential element of an EC STEM definition. The exclusion of 'the arts' from an EC STEM definition is contrary to a number of recent EC STEM meta-analysis (Johnston et al., 2022; Wan et al., 2021) that suggest STEAM is gaining popularity in EC as its emphasis on creativity and design thinking is more applicable to practice and learning in EC. However, the panel removed the focus on the arts and included play, curiosity, creativity, imagination, and critical thinking as essential in the definition. Some literature suggests that EC educators find the inclusion of the arts as a complication in STEM, and report significant anxiety around their capacity to engage in and support the arts in their practice (Probine, 2023). According to Burnard and Colucci-Gray (2019) merging the vast field of the arts with STEM leads to a greater possibility that educators will not possess expertise in all disciplines (visual arts, performing arts, craft and design, digital arts; science, technology, engineering, mathematics) which can risk core concepts and areas being overlooked or neglected. Therefore, adding creativity, curiosity and play as essential elements of this definition places emphasis on these important aspects without adding further expectations of educators regarding expertise.

Play is the dominant medium for learning in ECEC settings in many countries, and there was consensus that pedagogy is child-centred, an approach expressed in practice by children choosing what to do during extended free-play periods. Broad orientations rather than prescribed outcomes are the norm and play, child-led topics and local curriculum are common (Bennett, 2007). When compared to this approach the introduction of STEM is perceived as a change in the main function of ECEC, from providing children with care and holistic learning opportunities to preparing them for school (Fosse et al., 2018). The importance of play and child-centred learning is evident in consensus agreements and comments from the expert panel, for example:

> *'It is vital that play and curiosity feature as we define STEM. In this way it shows that the interest comes from the child's own curiosity and that using this curiosity through play is how the language and innovation develop. The environment must facilitate this investigation also'. (S2)*

Implications for Policy and Practice

This section outlines key points to be considered for EC policy and practice when defining EC STEM.

- *Play and Child-Centred Practice:* The importance of play and following children's interests was strongly felt. This point should be acknowledged and explicitly stated in any EC STEM policy, EC STEM CPD and in ECE initial education pertaining to STEM.
- *Creativity and STEM:* 'The arts' is not a crucial element of an EC STEM definition. However, creativity, play and exploration are deemed vital in any EC practice and should be reflected in EC STEM.

- *Defining EC STEM:* The definition of EC STEM is inclusive and wide ranging. It includes elements of STEM as a discipline *and* as instruction, as per Hasanah (2020). EC STEM definitions will include reference to 1) discipline content and 2) a pedagogical approach to learning and teaching. These elements are addressed further in the following bullets.
- *Disciplines suitable for EC STEM*: EC STEM is defined as any discipline-specific experience, activity, routine, or discussion. It can include any of the 4 individual disciplines of science, technology, engineering, math, or a combination of these disciplines. There is an understanding that integration of STEM disciplines often occurs during play or routines in EC settings. The expert panel caution that an excessive focus on single discipline areas could lead to prescriptive / adult led approaches contrary to EC philosophy and pedagogy.
- *Pedagogy:* The approach used in EC where broad orientations rather than prescribed outcomes are the norm and that play, child-led topics and design of local curriculum lends itself to integration of subjects as children follow their interest to create a curriculum. This conceptualisation aligns with that of the current ROI Curriculum Framework, Aistear (NCCA, 2009). Pedagogical approaches lean toward project approaches or ongoing/ long term investigations. Supporting children's dispositions of curiosity, creativity and imagination and their critical thinking rather than a focus on content knowledge or academic goals and the acquisition of information/ facts disconnected from context.
- *Dissent*: Experts highlighted that terminology and definitions are not what constitutes STEM practice, but the way it makes children feel. It is recommended

that the EC STEM definition used here act as a guide for practice but should not be used for monitoring or assessment purposes.

5.3.2 Section B. ECE and STEM

Consensus

Section B of the Delphi questionnaire pertains to how STEM should be conceptualised to fit within existing early childhood education, its function, structure, and focus. Consensus reached by the expert panel is particularly salient as agreements here can help to frame what STEM should look like in EC in ROI.

Level of consensus reached	Aspects of Early Childhood Education that should be reflected in the provision of EC STEM
Strong consensus	Play, active learning and hands-on experiences.
Strong consensus	Reflective of children's everyday lives and a focus on the everyday nature of STEM.
Strong consensus	Emergent approaches. Building on children's interests. Using children's interests as starting points for investigations
Strong consensus	Provision of opportunities to question and predict. Supports for creative thinking and meaningful problem solving
Strong consensus	Holistic learning approaches and support for children's holistic development
Strong consensus	Children's agency, child-led approaches, respecting children's freedom to make choices
Strong consensus	The use of everyday, simple and open-ended materials. The use of the outdoors and nature
Strong consensus	The provision of play invitations and prompts to provoke inquiry, engage curiosity and creativity
Consensus	Co-construction of knowledge between adult and child

Table 5.6 Consensus on aspects of ECE that should be reflected in the provision of EC STEM

Nine of twelve statements reached consensus in this section. Echoing views from section A, strong consensus is evident in the provision of EC STEM education that is play-based, active and child-led. The expert panel determined that EC STEM provision should reflect children's surroundings and everyday lives, and adopt emergent approaches that use children's interests, questions, and experiences as starting points for curriculum planning. For example:

> *'Inquiry and children's lived experiences are key. Project approaches are great if they remain child led. However, sometimes they can become quite adult-led. Understanding STEM might be different in an urban garden and a more rural environment with maybe more wild space is also important to remember.' (S2)*

Experts highlighted that EC STEM should use materials common in ECE settings (everyday, open ended resources and equipment) and avail of multiple learning spaces including nature and outdoor environments. This distinguishes the approach somewhat from more academic spaces and materials. Like opinion in section A relating to the provision of supports for the whole child (rather than a focus on academic or formal content/approaches) holistic learning approaches and support for children's holistic development was also agreed.

Level of consensus reached	The role of the EC professional in relation to STEM
Strong consensus	Foster and build on children's curiosity. Pose questions. Encourage wonder. Ask 'I wonder' questions
Strong consensus	Act as a play partner, co-constructor of knowledge, co-learner, collaborator, and make discoveries with the child. Respect child's ideas and initiations
Consensus	Notice and recognise STEM experiences happening in the setting, STEM ideas children are interested in, their existing funds of knowledge and plan to expand these. Provide new experiences /resources to extend on children's STEM and subject knowledge.
Consensus	Model and promote the language of STEM and STEM processes such as questioning, discussing, predicting, and experimenting.
Consensus	Be informed about EC STEM. Possess good content knowledge areas and concepts for each discipline. Confident to introduce and support EC STEM

Table 5.7 Consensus on role of the adult in EC STEM

Five of twelve statements in this section reached consensus. The *way* in which children should be supported to engage with EC STEM was agreed and is outlined in both **Table 5.6 and 5.7**. Building on the opinions from section A, experts made clear their ideas about pedagogy and the important role of the adult in supporting EC STEM:

> *'Educators play a fundamental role in fostering a positive and supportive learning environment that encourages exploration, critical thinking, and problem-solving skills in young children. They can encourage open-ended questions to stimulate children's curiosity and engagement with STEM concepts. Additionally, can provide scaffolding and support to ensures that children develop a strong foundation in STEM skills and knowledge.' (S3)*

The panel reached agreement that the adult role in relation to EC STEM is complex and that a thin line is tread between partnering and supporting children and taking over/ directing play and experiences. The adult is a facilitator, partner, and co-constructor who provides support and guidance while respecting children's ideas, initiations, and direction. At the same time, the adult role in noticing, recognising, and planning for STEM learning opportunities as part of an emergent curriculum is acknowledged. Prompts and provocations, modelling and demonstrating curiosity, and using wonder to invite children on STEM journeys are the methods proposed to support EC STEM. This section is summed up well by the following open-ended comment from one expert:

> *'Considerations of STEM pedagogy are hugely important. In making decisions about approaches and strategies, it's necessary to have a well-informed, holistic, and dynamic understanding of the babies, toddlers and young children. They need to be actively engaged regardless of the STEM learning processes, use of technology,*

indoor / outdoor learning environment. It needs to be meaningful and purposeful for the child.' (P3)

Finally, it should be noted that there were several comments from the expert panel indicating discomfort about guided and structured play experiences. From open-ended responses in round 2 and 3 of this section there appears to be hesitation about the inclusion of more structured or adult led approaches in ECE. For example, one expert remarked:

There is a place for guided play and more structured experiences as all children are different and learn in different ways and these can open new avenues for explorations. Some enjoy more structure and support in their learning. However, it would be provided alongside emergent interest project work and children being supported to follow and explore their own self-initiated curiosities. (E3)

Supporting Literature

ECE traditions and pedagogy acknowledge the integrated nature of learning, the crucial role of context, and the importance of play which distinguishes it from later education (Hayes, 2019). I argue that these factors should be understood and acknowledged when introducing STEM education to early childhood settings. Long-established 'laissez-faire' approaches in ECE are characterised by learning through play and exploration and pay little attention to disciplinary forms of knowledge i.e., science, technology, engineering, and mathematics (Wood & Hedges, 2016). The introduction of STEM is perceived as a change in the main function of ECE, from providing children with care and holistic learning opportunities to preparing them for school (Fosse et al., 2018). Literature has identified that educators are concerned that an academic emphasis in ECE will supplant play, undermine children's curiosity and intrinsic motivation to learn, and see well-being neglected in children's early years (Barblett et al., 2016; Schriever et al., 2020; Stipek, 2013). Concerns from the literature align with findings from this study where play, holistic learning, child-led and emergent curricula, and the use of everyday materials and environments were identified as essential in the provision of EC STEM. It is evident that the expert panel perceive aspects of ECE pedagogy and curriculum as fundamental to ECE practice, and that this should not change with the introduction or implementation of EC STEM. Instead, the way in which EC STEM is conceptualised should adapt to core/ unmovable elements of ECE.

The literature suggests that play-based practice already provides rich experiences to support understandings of STEM (Bers et al., 2018; Campbell et al., 2018; Speldewinde & Campbell, 2023; Stephenson et al., 2021) and that children's spontaneous play indoors and outdoors, and adult-led activities arising from children's free play, support integrated STEM learning (Campbell et al., 2018). Findings from the expert panel suggest that traditional materials, resources, and activities are favoured when supporting EC STEM. Similarly, findings of a recent meta-analysis suggest that a concerted effort is needed to recognise STEM in everyday experience in ECE (Johnston et al., 2022) rather than as subject based activity that requires specialised equipment, dedicated space, or materials.

Play is once again deemed central to findings in this section. As previously discussed, the literature highlights that numerous interpretations of play are evident across academia, policy, and praxis with the level of adult control is central to the debates (O'Síoráin et al., 2023; Pramling Samuelsson & Björklund, 2023). For example, who initiates and leads activity, the purpose and style of interaction, the nature of outcomes, goals of the pedagogical style, and what is assessed and how. Findings from the expert panel indicate that the adult role in EC STEM is similarly intricate where educators act as play partners, co-constructors of knowledge, co-learners, and collaborators, where children and adults are positioned as equals. This conceptualisation differs from the laissez-faire approaches of the past where the adult role was de-emphasised and educators were conceived of as 'passive providers of materials to foster developmental milestones' (Fleer, 2014, p. 41). Findings here suggest that the mediating role of the adult is crucial for learning; it is active, invested and can foster or amplify interests and learning. This supports points made by the US-based Early Childhood STEM Working Group (2017) about young children's ability to sustain EC STEM investigation alone. They argue that children's eagerness to affect the world around them and their natural curiosity may wain without guidance from others stating that young children 'need adult assistance to foster, guide, and build on their interests to ensure adequate early STEM experiences' (Early Childhood STEM Working Group, 2017, p. 12).

The concept of the adult as a 'skilled partner' has strong connections to Vygotsky's sociocultural theory (Gauvain, 2020). This theory is well-known and generally accepted in early childhood sector as an appropriate strategy for supporting children's learning, appearing frequently in literature pertaining to the role of the adult (Fleer, 2015; Hedegaard, 2002; Hedges, 2012). As part of this theory Vygotsky conceptualises the zone of proximal development as the 'distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers' (Vygotsky, 1978, p. 86). When examining practice pertaining to EC STEM, literature suggests that the adult plays a crucial role in supporting and guiding children and maintaining motivation and interest. ‘Children ask questions, but they may abandon those questions readily when they do not discover answers quickly; similarly, they may give up when the solutions they design do not work well the first time… the adult helps children define a problem they might solve, think about the goal, and encourage them to persist when designs fail.” (Early Childhood STEM Working Group, 2017, p. 13). With guidance, therefore, children can engage in more advanced cognitive activities than they could undertake alone.

Findings from this study position the adult in an active and intentional role in supporting EC STEM. In statements that reached consensus, terms such as ‘model’ ‘promote’ ‘foster’ and ‘build on’ were frequent. The complexity of EC curriculum and pedagogy cannot be summed up in binaries of adult-led versus child-led (Hedges, 2022; Wood & Hedges, 2016) and hand in hand, the role of the adult does not fit neatly into either category easily. In examining the adult role in a child’s learning, Gauvain (2020) states that assisting a child within their ZPD allows them to contribute to the surroundings in more complex and competent ways. She argues that interaction with a more experienced partner helps the child by 1) modelling strategies to solve problems 2) providing encouragement during complex tasks, 3) breaking activities down into manageable tasks 4) handling more difficult tasks so that the learner can focus on other parts (Gauvain, 2020).

As well as supporting children to tackle complex tasks, a specific interactive style between adult and child is implicit in agreed statements. Rather than a focus on academic learning, STEM supports children’s intellectual pursuits (Katz, 2010; Katz & Chard, 2000), and open-ended questioning and sustained shared thinking (Sylva et al., 2004) support children to think deeply. High level questioning that supports young children’s thinking, encourages wonder and indicates their engagement with the experience or materials are useful in EC STEM. Strasser and Mufson Bresson argue that the right type of high-level questions will ‘elicit complex language and excite the child to explain their ideas, signifies what they know rather than just recalling rote information and encourage children to expand their thinking and perspective on a subject’ (Strasser & Mufson Bresson, 2017, p. 6). Results in this section highlight the need for educators to be competent communicators who can prompt, elicit interest, and encourage children’s engagement and motivation without dominating activity. The active role of adults is outlined as a guiding principle in STEM policy (Department of Education, 2023b; Early Childhood STEM Working Group, 2017; Murphy et al., 2019; OECD, 2020b) and modelling language and use of tools and resources. When supported by knowledgeable adults ‘children learn to think, calculate, and create like scientists, mathematicians, and engineers. Rich, adult-facilitated STEM experiences in preschool help children develop the skills and habits of mind that will prepare them for later competencies in STEM disciplines’ (Early Childhood STEM Working Group, 2017, p. 13)

Implications for Policy and Practice

This section outlines key points to be considered for EC policy and practice when considering how STEM should be conceptualised to fit within existing early childhood education, its function, structure, and focus. Consensus reached by the panel indicate the following inferences for policy and practice:

- *Respect for EC traditions*; Central elements of ECE should be respected and maintained. For example, EC STEM retains play and hand-on learning as core to curriculum, considers child agency as fundamental, and children's lives, interests or ideas are starting points for STEM investigation.

- *Traditional materials*: Bespoke or subject-specific STEM materials are unnecessary in early childhood settings. Traditional EC materials, for example, sand, water, junk and open-ended materials, and access to nature and outdoor spaces will provide ample opportunities for EC STEM.
- *Active role of the adult in supporting EC STEM*. The adult role in STEM is active, intentional, and characterised by support, guidance, modelling, and provision of challenge for the young child. The adult and child work together to discuss, agree a course of action, investigate, problem-solve, and cooperate to achieve their goals. This role differs from traditional conceptualisations of the adult as a hands-off provider of materials and observer of child activity.
- *The adult as provider of STEM resources, opportunities, and modeller of EC STEM:* EC STEM requires adult support. STEM content and processes may be unfamiliar to children. Simple prompts or play invitations can spark interest, trigger curiosity, creativity, and inquiry and lead to new learning.
- *The adult is knowledgeable regarding EC STEM:* The adult must align their knowledge of emergent and inquiry-based curricular approaches, planning, and experiences with knowledge of EC STEM. To do this effectively the educator should possess good STEM content and process knowledge and be confident in supporting EC STEM.
- *Dissent*: Of ongoing concern is the introduction of structured, adult led or solely academic STEM activities or lessons. Instead, the introduction of EC STEM should come with caveats about respect for EC traditions and use of traditional materials as

outlined in the bullets above. This will allay fears about inappropriate STEM practice in EC settings.

5.3.3 Section C. Essential Knowledge, Pedagogy, and Dispositions.

Consensus

Section C is concerned with identifying the knowledge, pedagogy, and dispositions that EC professionals must possess to support EC STEM. As STEM is a relatively new area in ECE and 'not the core business of early childhood' (Fleer, 2021, p.3), identifying the essential concepts, approaches, and attitudes that might support the identification and/ or provision of STEM experiences is a first step in supporting the development of this knowledge and associated skills. Panellists were asked to consider three areas of ability 1) STEM knowledge, 2) STEM pedagogy and 3) dispositions required to support STEM learning.

Level of consensus reached	Essential KNOWLEDGE early childhood professionals require to successfully support early childhood STEM.
Strong consensus	How play, inquiry-based learning, and the emergent curriculum framework support EC STEM.
Consensus	Knowledge of co-construction, how to research STEM topics with children, model learning as opposed to knowing everything; Foster a learning mind-set.
Consensus	How to adapt or tailor STEM for age group (babies, toddlers, young children).
Consensus	Knowing where and how to access knowledge to support STEM investigation. Researching topic areas to increase knowledge and extend STEM learning experiences.

Table 5.8 Consensus on essential knowledge required to support EC STEM

In this section, four of thirteen statements reached consensus. Panellists had strong opinions about the value of play within emergent inquiry-based curricula. This bolsters consensus reached in sections A and B where similar findings were evident. Strong consensus was reached that educators would require the knowledge to support EC STEM as part of an emergent and inquiry-based curriculum, which is promoted in Aistear (NCCA, 2009) the Irish curriculum framework for early childhood. Moving away from these common agreements a more practical emphasis was identified in this section, for example, being able to tailor EC STEM for different age groups within ECEC or having the ability to source appropriate and accurate information to support EC STEM learning. For example, one panellist observed:

> *'the last point - knowledge of how to access knowledge to support STEM investigation AND the confidence to do this - are probably the most important features.'* (panellist's emphasis) *(A5)*

As this section focused on knowledge requirements, it is surprising that there was so little agreement about EC STEM content knowledge or discipline-specific content knowledge i.e. science, technology, engineering, and mathematics. While not a position frequently expressed by the wider panel, one comment from an expert centres on this point and may provide some insight:

> *'I think educator knowledge of STEM subject matter is not as important as the educator having knowledge of co-construction, researching with children, demonstrating curiosity and creativity, and knowing where and how to access knowledge to inform and progress STEM learning.' (S1)*

Level of consensus reached	Essential PEDAGOGICAL approaches professionals require to successfully support EC STEM.
Strong consensus	Open-ended play and exploration. Playful learning
Strong consensus	Strong, meaningful, and trusting relationships with children.
Consensus	Extending children's interests. Recognising and building on funds of knowledge, starting from where the child is
Consensus	Pedagogical documentation. Be able to observe, write learning stories for next steps in planning and expanding interests.

Table 5.9 Consensus on essential pedagogy required to support EC STEM

The panel agreed on the importance of 4 out of 15 statements in this section. Items that reached consensus on pedagogical approaches are somewhat generic, focusing on play, child-led approaches, and strong relationships, but do reflect responses in previous sections of the questionnaire. Expanding on agreements in section B, experts agreed that an ability to identify, document and expand STEM learning was essential for EC professionals.

Level of consensus reached	Essential DISPOSITIONS/ ATTITUDES EC professionals require to successfully support EC STEM.
Strong consensus	Happy to be with children. Find pleasure in their work.
Strong consensus	Have a belief in children's abilities. View of children as confident and capable learners.
Strong consensus	Adaptable in the moment, flexible, open to change
Strong consensus	A willingness to be playful.
Strong consensus	Observant
Strong consensus	Able to say, 'I don't know, let’s find out'.
Strong consensus	Respectful, responsive attitude to children's ideas and innovations
Strong consensus	Good communicator
Strong consensus	Patient
Strong consensus	A willingness to develop pedagogical content knowledge in STEM, view themselves as a learner
Strong consensus	Comfort with and willing to fail or make mistakes. Willingness to step outside of their own comfort zone.
Strong consensus	Interested. Wonders about things.
Strong consensus	Reflective
Strong consensus	Positive disposition to STEM learning themselves.
Consensus	Curious. Possesses a general orientation that is curious about understanding the world
Consensus	Resourceful
Consensus	Imagination
Consensus	Positive disposition toward STEM, positive views on the use of technology
Consensus	Enthusiastic. Passionate
Consensus	Resilient

Table 5.10 Consensus on essential dispositions required to support EC STEM

A great number (20 out of 21) of statements in this section received strong consensus or consensus. Agreement between expert panel members is the goal of the Delphi procedure, but many of the statements in this section are general and not specific to STEM e.g. Happy to be with children; find pleasure in their work; observant; resilient and this was identified by several of the panellists, for example:

> *Some of the characteristics listed are essential for early childhood professionals regardless of a STEM focus. (A2)*

Others disagreed, pointing out that dispositions that may appear universal are strongly connected to STEM education. For example:

> *Resilience is crucial for educators when teaching STEM to children because it enables them to adapt to the dynamic learning environment, respond effectively to challenges, and preserve through setbacks. Educators with resilience can model positive attitudes towards problem solving, learning from failure and embracing the iterative process*. (S3)

Expert consensus was achieved with statements that had a stronger STEM lens including reference to positive dispositions toward STEM learning (for the educator), and positive view on the use of technology. In addition, several statements that position the adult as a novice, a beginner, and a learner alongside children in relation to STEM were agreed by the panel. Strong consensus was also reached on the statement ‘A willingness to develop pedagogical content knowledge in STEM, view themselves as a learner,’ which is somewhat contradictory considering that content knowledge was not deemed important in earlier parts of this section or in previous sections of the questionnaire.

Supporting Literature

Knowledge, pedagogy, and dispositions required to support EC STEM rarely appear in the literature, where the focus remains on challenges, child outcomes, enabling environments or educator STEM beliefs and self-efficacy (Belbase et al., 2021; Johnston et al., 2022; Wan et al., 2021). In this study, it was considered necessary to identify the abilities EC educators would require in their role as co-constructors of EC STEM experiences. Literature suggests that little time is given to content knowledge in initial educator education or in ongoing PD (Brenneman et al., 2009; Department of Education and Skills, 2020b; Lange et al., 2021; O'Neill et al., 2022, 2023; Ryan et al., 2014). Multiple international research studies indicate that EC educators do not acquire sufficient STEM content knowledge in initial education, leading to poor self-efficacy and issues implementing STEM in their settings (Chan et al., 2023; Park et al., 2017; Yıldırım, 2021). While the expert panel did not agree that discipline-specific knowledge is required, the literature continues to find that EC educators have a lack of knowledge and experience in STEM education, limited content knowledge and difficulty integrating the knowledge and skills of different disciplines (Çiftçi et al., 2022). The literature is clear; educators in all areas of education require support and ongoing professional development in relation to STEM (Belbase et al., 2021; O'Neill et al., 2023; Park et al., 2017; Wan et al., 2021). In EC, time allotted to prepare educators in STEM is limited (Brenneman et al., 2009; Lange et al., 2021; Ryan et al., 2014). Consequently, EC educators have a lack of knowledge and experience in STEM education, limited content knowledge and difficulty integrating the knowledge and skills of different disciplines into their pedagogy (Brenneman et al., 2009, 2019; Çiftçi et al., 2022). Currently, there are very few EC STEM supports for educators in ROI and requirements that this content be included in ITE are limited (Department of Education, 2023a; Government of Ireland, 2023). As such, changes are required at a national level if EC STEM is to be meaningfully enacted.

The panel reached consensus on two specific actions in this section 1) that educators require the ability to source accurate STEM information and resources to support their practice, and 2) that educators be able to tailor STEM for the age of the children they work with i.e. babies, toddlers, and young children. Recent research in Ireland has demonstrated that educators struggle with both tasks. Even highly qualified and experienced educators report being unaware where to access EC STEM resources online (O'Neill et al., 2023). Similarly, educators report being unsure about how to tailor their practice to support EC STEM for all age groups in ECE settings (Department of Education and Skills, 2020a; O'Neill, 2021). Thus, to enable all educators to achieve/ master these essential EC STEM knowledge, pedagogy, and dispositions, they will need information and guidance in relation to each of these points.

A recognised challenge with consensus methods such as Delphi, is the possibility of generating broad output rather than sufficiently detailed statements (Bolger et al., 2011; Chang et al., 2011; Hsu & Sandford, 2007; Saffie et al., 2016). Topic specific information can be lost as experts alter their opinions to achieve consensus (Saffie et al., 2016). Further, in Delphi studies where the statements are developed based on open-ended questions in the first round, as in this study, statements generated are only as good as input from panellists who may have less subject specific or in-depth knowledge (Hsu & Sandford, 2007). As this is a new research area, the expert panel could be unsure of the knowledge, pedagogy, and dispositions required to support EC STEM. Alternatively, the results may signify that specific STEM knowledge, pedagogy and dispositions are unnecessary. While this may be the case, I argue that the former is more likely. In this and previous sections of the questionnaire the panel have agreed that specific knowledge and pedagogy are required to support EC STEM.

It should be noted that consensus in this section conflicted with statements in sections A and B of the questionnaire. For example, statements related to content knowledge i.e. knowing what children should /could learn and understanding progression continua (or the steps children' take toward achieving learning in particular STEM areas), were not considered essential. However, the panel did agree that educators need to be able to identify and know how to document learning in relation to STEM and plan for children's next steps and expanding interests. This implies some sort of understanding of how to categorise babies, toddlers, and young children's STEM learning and how children build understanding of STEM concepts or discipline specific information.

Implications for Policy and Practice

This section outlines key points to be considered for EC policy and practice in defining the essential knowledge, pedagogy, and dispositions necessary to support EC STEM.

- *EC STEM knowledge:* Educators require knowledge specific to EC STEM. This includes knowledge of co-construction, modelling and fostering a learning mind-set; tailoring STEM experiences for different age groups (babies, toddlers, young children) and knowing where and how to access information to support EC STEM investigation.
- *EC STEM pedagogy*: Common ECE pedagogy such as the use of open-ended play and exploration; the creation of strong, meaningful, and trusting relationships with children; extending children's interests; and recognising and building on funds of knowledge will support EC STEM. Pedagogy specific to EC STEM is also required including the ability to co-construct meaning, model a learning mindset, and use pedagogical documentation to capture and plan for next steps in children's STEM learning.

- *EC STEM Dispositions:* Essential STEM dispositions include a positive disposition toward STEM learning (for the educator), a positive view on the use of technology and a willingness to develop pedagogical content knowledge in STEM and view themselves as a learner.
- *STEM Policy:* Funding for PD and ongoing support is required to meet policy and inspection requirements. If this is not enacted, policy and inspection criteria should be reconsidered to reflect current provision and EC STEM understanding.

5.3.4 Section D. Support and Professional Development. Consensus

This section pertains to the way in which EC professionals should *be enabled* to understand and support EC STEM within their practice. It focused on what training and supports EC professionals need, and the structures required to ensure this can happen. Statements about the type of PD, ongoing support and resources were considered, as well as sector wide structures and responsibilities that could enable the sector to become more familiar with EC STEM.

This section experienced the greatest amount of change from round 2 to 3, and the least response stability, suggesting panellists changed their opinions from one round to the next. See **Appendix 9** for details of response stability for each statement.

Level of consensus reached	**Effective methods of organising and facilitating EC STEM professional development.**
Strong consensus	Ensure play is at the forefront of how STEM is considered in practice. Provide examples of how subjects can be integrated in a play environment
Strong consensus	Support providers to notice and meaningfully engage with STEM already present in the daily routine, activities, and curriculum.
Strong consensus	Time for reflection. Consider what early childhood STEM looks like in their practice.
Consensus	Incentives for educators and supportive conditions for STEM professional development (replacement staff, paid training, time in lieu, professional development during work hours)
Consensus	Learning by doing with hands-on experiences using STEM materials and processes. For example, using technology, digital artefact creation, project work
Consensus	Include opportunities for peer learning, sharing practice and analysing exemplars from practice.

Table 5.11 Consensus on PD methods to support EC STEM

The panel agreed on methods to organise and facilitate EC STEM professional development, but these were not comprehensive. Methods that supported the integration of new knowledge and understanding, reflection on their own preconceptions, and application to their day-to-day practice were identified as important and reached consensus from the panel. Once again, the importance of play was addressed and the panel established that any PD should include examples of how STEM subjects can be integrated in a play environment to enable educators to notice, support and extend the opportunities for STEM already present in the daily routine, activities, and curriculum. Additionally, an element of applied learning was deemed important including the opportunity for educators to 1) personally experience the use of EC STEM materials and processes and 2) share their ideas with peers and analyse examples from other people's practice. Open ended comments reflected these points. For example,

> *I think delivery of CPD should be in person where at all possible as this provides a better forum for overall engagement with tutor and course content, opportunities to questioning for understanding, sharing experiences, and supporting peers and peer learning. (S4)*

> *In relation to the Community of Practice, an approachable, experienced peer mentor would be a supportive aspect to guide discussion and help problem solving. (S2)*

While it is useful to have agreement in relation to how PD should be structured and the pedagogy and experiences included, it is disappointing that there was no agreement in relation to the content of this PD, especially in relation to discipline-specific content knowledge or processes. A core element of any professional development includes learning about the topic/ topics of focus. Without this, I argue that one part of a triumvirate (how, why and what of professional development) is missing. This may indicate that even among experts the conceptualisation of STEM is still limited, and a deep knowledge of how processes like the *Engineering Design Process* or *mathematising* are relevant to many different aspects of children's learning (O'Neill, forthcoming) are identified as a knowledge gap.

Level of consensus reached	Effective methods of supporting EC professionals after STEM professional development.
No consensus reached under this heading.	

Table 5.12 Consensus on methods of supporting EC professionals *after* STEM PD

In this section, follow-on supports for professionals *after* engaging with EC STEM professional development were examined. Consensus was not reached on any statements under this heading. This is a reduction in consensus from round 2 where three of the five statements reached consensus. See **Appendix 9** for further details. Moreover, the lack of agreement here could call into question consensus in previous sections of the questionnaire. For example, when asked to consider the previous topic in this section 'Effective methods of organising and facilitating EC STEM professional development (T**able 5.11**) the panel reached consensus that incentives for educators and supportive conditions for STEM professional development were required, as were access to technology. But when asked to consider similar statements for support *after* CPD no consensus was reached. This could indicate that the panel consider follow-up support less important than initial CPD, but open-ended comments shed light on why this anomaly might be presenting itself:

New materials and resources not as important as all the others. I would rather see facilitation of educators seeing supports available for STEM learning… than more stuff. (E3)

Provision of STEM resources and materials is only somewhat important. STEM activities do not require expensive materials and arise in play with materials that are not considered STEM materials. (A2)

Where dissent was expressed to this idea, a sense of frustration was obvious that EC has less investment when compared with other parts of the education system.

I strongly feel we need resources and materials as much as we need training and supports. We should have an expectation to have access to both... look at the primary school sector, they have funding for resources as well as CPD. (A1)

Finally, one expert pointed out the need to have any PD positioned within existing structures and policy stating:

> *Support for STEM should not be provided in isolation - important that it is situated within a framework like Aistear, must be part of supporting the development of the competent, confident agentic learner nestled in a slow nurturing pedagogy and underpinned by play and hands on experiences indoors and outdoors. (P2)*

From this statement and others, it could be possible that experts are focusing on the next step or what is important right now, rather than looking at a long-term approach to STEM CPD.

Level of consensus reached	Features of organisation that need to be in place to scale up EC STEM professional development.
Consensus	Establish broader coalitions that enable multiple stakeholders to learn together and create a shared language and understanding i.e., educators, academics, mentors, inspectorate, curriculum bodies and EC policy makers.

Table 5.13 Consensus on features of organisation that need to be in place to scale up EC STEM PD

From 14 statements included in this section, only one reached consensus at the end of the Delphi process (compared to one strong consensus and five consensuses in the previous round). The statement that did reach consensus is an interesting one, as it positions all stakeholders as equals with something to learn from one another. Perhaps this indicates that there is a preference for 'learning together' and that all approaches to consultation and training in future need to be framed in this way. Then again, this could indicate a desire for consultation and for expertise existing in the sector to be acknowledged and valued. Similar statements in this section that did not reach consensus include *A clear vision for early childhood STEM across the sector. commitment from multiple government departments with responsibility for EC* and *Creation of a STEM interdepartmental group. Division of roles and responsibilities including roll out of national early childhood STEM professional development.* Trying to unpick the reason why these examples did not reach consensus, I posit that these examples imply a more top-down approach, when something more equitable is favoured.

Open-ended responses suggest a mistrust of government departments and those identified as 'experts'. For example, statements referring to the identification of STEM skills and knowledge requirements by STEM experts and/ or government departments were met with some scepticism:

I have concerns about Government departments taking responsibility for STEM PD. The content for STEM PD should be identified by early years professionals themselves and lead by those professionals. Government departments cannot know what is appropriate and practical 'on the ground' in early education settings. (A2)

Agreement by experts on EC STEM skills- this is unclear, so I have indicated not important. It would depend on who the 'experts' are. Experts on STEM for older children may have ideas that are not appropriate for early years. (S1)

There were a significant number of open-ended comments in this section, and in expert comments at the end of the final questionnaire that referred to this proposal. It appears that elements of the statements in this section were problematic. For example, round 3 open-ended comments indicate some level of discomfort with allowing government department to make decisions about local EC practice:

I'm not sure about some of the questions in this section. We need to focus on what is best for children not what government departments think at different points in time. One day it is literacy and numeracy, another day it is STEM. (P2)

Round two open ended comments in a similar vein, expressing concern about a top-down approach focusing only on outcomes. They include the following:

I would be nervous as to what the STEM PD would look like if government departments take responsibility for the content. I think they can be responsible for the overarching ideas and aims, rather than the content. (S2)

Aligning professional development to a set of required skills, government departments taking responsibility for STEM evaluation etc. reflects a neoliberalist *perspective. The inclusion of STEM should not be a requirement from outside departments/agencies. It is my view that STEM should be included because professionals 'want to' not because they 'have to'. (A2)*

Need to place STEM within holistic learning and development, only one part. Am fearful of a push down of subjects… we need to be really careful here. (P2)

Dissent in this section could be attributed to worry about aforementioned issues, which need consideration if EC STEM is to be enacted in ROI.

It is worth noting that open-ended responses in this section were delineated by role to a greater degree than in others. Many experts commented on their particular ‘patch’ and discussed what was needed. For example, those in support roles focused on what they deemed most needed - help for managers and educators:

At a service level you need supportive leadership that champions the integration of STEM, adequate infrastructure, technology, and resources to facilitate effective STEM learning and professional development opportunities for educators to enhance their understanding and teaching of STEM concepts. At an Educator level opportunity to engage in collaborate (sic) learning and sharing of best practice and access to relevant curriculum resources and materials that support the implementation of STEM. (S4)

I do feel it is important to assess current knowledge and provision in relation to EC STEM and hear from educators in order to inform the development of CPD content and identify the most effective methods to structure ongoing supports. (S3)

Educators' comments reflected more practical stance pertaining to the need for changes to initial education and further training, and support from government departments. For example:

> *I feel that including STEM material through all QQI level would ensure that it is seen as important, as currently I think that STEM is seen as something done by people with degrees or higher (E1)*

> *More focus on EC STEM from department of education [DES] in terms of inspections, parameters for initial learning and professional development and defining EC STEM learning. (E3)*

Policy responses were mixed and included the following:

> *Professional learning for early years educators needs to be core to consideration around STEM learning. Professional learning should be provided in a flexible manner depending on the contextual needs of a setting and the educators. There needs to be variety and scope in terms of the professional learning being provided. The role of the leaders within a setting cannot be overestimated. Professional learning needs to bring about improved STEM learning for babies, toddlers, and young children (P3)*

> *We need to focus on what is best for children, not what government departments think at different points in time… Why should they set the focus for early learning with no consultation on the citizens themselves - children under 6. Focusing exclusively on STEM as set out above raises red flags. Instead, I suggest supporting the holistic development of the child as set out in Aistear. Proper training and*

resources on supporting engagement with our national framework and the STEM opportunities within it would be a much better goal in my opinion. (P2)

Supporting Literature

This study's underpinning research question is 'how should STEM education be implemented in ECEC in ROI?'. Considerations of how children, educators, and EC settings would enact STEM were paramount, but consideration of the wider EC landscape was always considered necessary. This section attempted to ascertain what supports, structures and actions were required at a national level. Enactment of education policy requires funding (Rizvi & Lingard, 2010) and it is strongly recommended that governments invest in development of high-quality PD for ECEC that is based on research, easily accessible and improves pedagogical knowledge, understanding and skills of ECEC educators (Rogers et al., 2020a, 2020b). Poor working conditions in ECE in ROI (OECD, 2021b, 2021a) and limited funded continuing professional development may also contribute to poor uptake of STEM PD, if provided. This study highlights the need for incentives for educators and supportive conditions for STEM professional development like other parts of the education system to include replacement staff, paid training, time in lieu, professional development during work hours.

STEM PD often necessitates considerable shifts in pedagogy, curriculum, and assessment approaches (Margot & Kettler, 2019). Adult learners benefit from sustained and tailored PD that involves cognitive, motivational, and emotional dimensions of learning, and is therefore more effective at influencing educators' behaviour (Korthagen, 2017). Empirical study stresses that educators present with preconceived ideas about STEM and require time to reflect on their own conceptions and interrogate their beliefs, individually and with others (Ring et al, 2017; Pacini-Ketchabaw, 2022). Corresponding findings from this study detail the need for opportunities to explore examples of EC STEM, analyse exemplars from practice, share ideas, and consider how learning could be applied or adapted in their own setting. Without this feature of PD, the approach may conflict with educators' beliefs and understandings and the learning goals will not be met (Ring et al., 2017). This point is particularly significant considering the findings outlined in section B which underscore the importance of respecting ECE traditions and adapting EC STEM to it, rather than the other way around.

The panel suggested that opportunities to allow multiple stakeholders i.e., educators, academics, mentors, inspectorate, curriculum bodies and EC policy makers are needed to create a shared language and understanding regarding EC STEM. This position aligns with literature from the ROI that highlights the necessity for 1) national consultation with diverse stakeholders from practice and policy to promote greater cohesion in the delivery of ECEC arising from that policy change (Hayes & Duignan, 2017); 2) The need to work with, and consult with the sector to create buy-in, draw on expertise and overcome issues unique to the ECEC sector in ROI (Hayes & Duignan, 2017; Hayes & Urban, 2018; McCormilla, 2018); 3) respond to the varied professional profiles of the ECEC sector in Ireland and support learning from more knowledgeable peers (Government of Ireland, 2023; O'Neill et al., 2022, 2024) and 4) use existing support structures and organisations who are aware of local/ regional needs to facilitate PD as these are positively viewed and recommended by educators (O'Neill et al., 2023).

An aim of this study was to create a roadmap for educators and the sector at large to guide the implementation of STEM in ROI. From this perspective it is disappointing that more statements did not reach consensus in this section. Literature pertaining to EC educator PD and EC STEM PD suggests that long-term supports are most effective in impacting practice (Korthangan, 2017) but that most STEM professional development for educators is short, patchy, ineffective, and does not take into consideration the educator's specific needs (Wilson, 2011). Brief, one-off PD does little to challenge beliefs about STEM, build confidence, develop understanding, or build educator's capacity to engage in STEM pedagogies (Fraser et al., 2018). Often the focus of STEM PD is an intellectual understanding of STEM theory without an emphasis on enactment in practice. Short term training is insufficient to transfer STEM content knowledge and impact confidence enough to give rise to real change in EC settings (Wan et al., 2021). Policy solutions are often streamlined and designed for a quick-fix solution (Fullan, 2016). Policy makers must be made aware of the need for increased time for educators to work together to create innovative ways to successfully integrate STEM education in their settings and identify their ongoing training needs (Margot & Kettler, 2019). Specialist coaching, mentoring and peer-to-peer reflection are flexible PD models that offer the responsive approach required where a diverse workforce has a wide variation in skills, knowledge, and qualifications (Rogers et al., 2020a). Stephenson et al (2021) found that PD with follow up support on site led to a positive shift in the motive orientations of early childhood teachers and increased both competence and confidence with the intentional teaching of STEM.

Implications for Policy and Practice

This section outlines key points to be considered for EC policy and practice when designing and organising support for initial and ongoing professional development of EC professionals within the EC sector.

- *Examining everyday STEM:* An ability to identify the STEM opportunities in practice are necessary to support EC STEM. EC professionals require opportunities to explore examples for babies, toddlers and young children and support to identify STEM experiences that already exist in their setting/ practice. This requires an ability to identify and categorise STEM experiences and activity.
- *Applied Professional Development:* Application to practice is deemed essential and will support educators to begin to apply their learning in their setting. EC professionals will, therefore, need access to STEM materials, however basic, and support from others who are familiar with STEM processes and the use of typical EC resources using a STEM lens.
- *Sharing expertise:* Of great importance is the requirement to share expertise about this new area of EC practice. This includes sharing among peers *and* between experts from a variety of EC professions (educators, academics, policy, and support).
- *Ongoing supports*: changes to thinking do not necessarily lead to change in practice. A long term and sustained approach to supporting EC STEM is required. A specific avenue was not agreed by the expert panel. However, literature from the ROI suggests that current structures such as Better Start, City and County Childcare Committees and National Síolta Aistear Initiative, could be adapted to include STEM content.

- *Making STEM visible*: If EC STEM continues to be a practice/ inspection/ curriculum requirement it needs to be specifically named in Aistear and other relevant policy documents to demonstrate how it is relevant and meaningful in ECE.
- *An EC STEM vision*: A clear, concise vision pertaining to EC STEM is needed to develop a shared language and understanding among stakeholders. While these ideas did not reach consensus within the Delphi process, I argue that this is a new area of ECE research and practice which requires leadership, explanation, and time to bed down.

5.4 Dissent

Of equal importance in a Delphi study is an exploration of dissent among the group. This data is of significance to accurately understand what pitfalls or issues may arise as EC STEM is being implemented with a variety of EC professionals. Delphi is a consensus method, but it is also an effective tool to identify conflicting or divergent points of view, opposition to proposals, and patterns in dissent. Strongly held opinions that are contrary to agreements and that persist throughout the process, even in very small numbers, are notable. From a government perspective, they represent points that require careful consideration if any policy is to be successfully enacted.

> "The process tends to move the group's responses toward consensus, although reaching consensus is not necessarily the central objective or a measure of success of such studies. It also produces a set of *reasons* behind the responses. The value of the Delphi method rests with the ideas it generates, both those studies that evoke consensus and those that do not." (Gordon & Pease, 2006, p. 322). [my emphasis]

This is a particularly salient point in relation to this study. Understanding dissent and opposing opinions may highlight which ideas and positions are intractable, which are open for wider debate and discussion, and how these may differ depending on the stakeholder (educator, policy or inspection role, curriculum development, setting support or mentoring), leading to a clearer understanding of EC STEM beliefs and perceptions among stakeholders. This section identifies changes in opinion that experts expressed in open-ended comments, statistical data that illustrates change in opinion from round to round, and compares opinions based on expert cohorts i.e. policy, support, educator, academics, and between experts from the ROI and those from outside this jurisdiction.

5.4.1 Change Over Time

One of the key reasons that Delphi is completed over several rounds is to investigate how opinion changes over time (Dalkey & Helmer, 1963). Changes in opinion based on the impact of *other experts'* comments was evident. All but one expert made several comments in each questionnaire. This outlier (policy) did not make any comments in round 2 or 3. All other panellists made contributions in round 2 and 3 that were shared with the group as part of the feedback process. Some of the panellists commented on how the opinion of others swayed them, or how coming back to statements encouraged them to reconsider their initial ratings. For example:

> *On reflection I have a stronger rating for B6, on support for holistic development being reflected in the provision of EC STEM. I feel this is needed to make sure policy and practice directions for EC STEM don't get overly focused on teaching STEM content. (A1)*

Across all sections of the Delphi questionnaire, panellists identified frustration that statements they agreed with strongly, were not shared by the group. For example, several panellists complained that a statement about the language of STEM was omitted from the requirements of a STEM definition. One explained:

> *‘Incorporating the language of STEM is a key aspect of STEM literacy for everyone and an opportunity to support wider literacy, precision (for Maths and Science learning and thinking) and children's growing content knowledge. It should be included.’ (E3)*

Panellists were discouraged when statements perceived to be crucial in meeting policy requirements did not reach consensus. One expert remarked:

> *‘I am disappointed that B15- 'support children to use technology' did not reach consensus. Considering the very recent 2023 OECD report on Empowering young children in the digital age; they highlight that young children need to be supported to develop their digital literacy as part of their ECEC experiences, as it helps to provide equal opportunity, a start of reducing the digital divide… Based on this I feel ECEC in Ireland has an important role to play in supporting children's use of tech.’* (A1)

Similarly, frustration was expressed when actions that are recommended in the literature were not deemed essential by the panel:

> *The research and literature suggest that practice-based PD taking place in the EC setting can be valuable for EC educators when they might feel concerned or challenged with some of the STEM areas, particularly technologies. (A5)*

5.4.2 Dissent Analysis

Dissent can reveal valuable insights for the practical and academic discussion emerging from a Delphi study (Beiderbeck et al., 2021; Schmalz et al., 2021). Stakeholder-group analysis, outlier analysis, bipolarity analysis are common elements of Delphi dissent analysis (Dijkstra et al., 2023) and are discussed below to explore patterns in this data.

5.4.3 Stakeholder-group analysis

The panel included experts from a variety of backgrounds including policy, support and mentoring roles, educator/ managers, and academic or research roles. For more detail about how expertise was categorised, and the self-reported expertise of the panel see **Appendix 7.** To identify if dissent arose based on type of expertise, responses to the 120 questionnaire statements in rounds 2 and 3 were organised by cohort and compared i.e. stakeholder-group analysis**.** The overall panel consists of a small group of 15 and once broken by cohort some groupings contain only two individuals. Therefore, findings cannot not be generalised but offer some insight into how statements might be viewed through a variety of expert lenses. Mean responses per questionnaire section are outlined by cohort in **Table 5.14** and comparison of international and national groupings are outlined in **Table 5.15**

Cohort	Section A STEM Definitions	Section B ECE and STEM	Section C, Knowledge Pedagogy	Section D PD and Support
Overall Mean	4.5	4.6	4.6	4.1
Policy	4.8	4.8	4.7	4.0
Support roles	4.3	4.4	4.5	4.3
Educators	4.4	4.7	4.7	4.5
Academics	4.5	4.6	4.7	3.9

Table 5.14. Overview mean agreement by section expert cohort.

Acknowledging that the mean response rate is a rather blunt instrument when analysing data, it proves useful in illustrating some pattern in responses among expert cohorts. For example, educators deemed PD and support more important than academics or those responsible for its provision i.e. support and policy cohorts. When comparing experts from different jurisdictions, international experts had lower scores in relation to PD and support due to their self-reported lesser knowledge about the EC sector in the ROI.

Cohort	Section A STEM Definitions	Section B ECE and STEM	Section C, Knowledge Pedagogy	Section D PD and Support
Overall Mean	4.5	4.6	4.6	4.1
ROI	4.5	4.7	4.7	4.2
International	4.5	4.5	4.5	3.8

Table 5.15. Overview mean agreement by expert jurisdiction.

Round three data were eyeballed for any difference of opinion between cohorts in relation to specific statements or ideas. For example, international experts consistently rated the concept of slow nurturing pedagogy poorly when equated to ROI counterparts. **Table 5.16** and **Table 5.17** provide examples of some further inconsistencies identified. Statements broadly relating to the intentionality of the educator were grouped together and cohort responses compared. Only one statement (C5) in Table 5.16 reached consensus. In the main, academic and educator cohorts expressed more positive opinions suggesting they deem statements pertaining to educator intentionality more favourably.

	Sample Grouped Statements Intentionality of the Educator	Overall Mean	Policy Mean	Support Mean	Educator Mean	Academic Mean	Internat-ional Mean
B13	Provide guided play experiences, and more structured materials or activities based on the child's STEM interests.	3.6	3	3.3	4	4.3	4.5
B16	Where necessary, explicitly teach STEM concepts such as counting or life cycles	3.3	2	2.8	5	4	3.5
B19	Be aware of progression in STEM concepts and processes. Have the ability to use these in integrated, and in single-disciplinary ways.	3.8	4	3.8	4	4.8	5
C3	STEM fundamental concepts and processes (for example iterative design; problem finding and problem solving; theory generation)	3.8	3	3.5	4.5	4.3	4
C5	An understanding of key STEM developmental progressions. Knowledge of how to assess and plan for children's STEM progression based on interests and current knowledge.	4.5	4	4.5	5	4.8	4
C6	Appropriate STEM language including math language. Knowledge of the importance of questioning, discussing, talking with children about STEM subjects	3.7	4.7	4	5	4.5	4
C25	Early maths pedagogical approaches. For example, maths talk, counting principles, mathematising.	4.2	3.7	3.8	4.5	4.8	5

Table 5.16. Comparison of mean agreement on statements pertaining to educator intentionality.

Literature suggests that educators remain suspicious of technology (O'Neill, 2021; Schriever et al., 2020) and that long- held and largely invisible beliefs and practices such as the exclusion of technology from EC environments, are hard to change (Cochran-Smith et al., 2020). Table 5.17 summarises several statements related to the use of technology as part of EC STEM, none of which reached consensus in this study. These results suggest that those in policy and support roles are least likely to deem technology use essential, while academics awarded the highest ratings, closely followed by educators.

Sample Grouped statements – Technology		Overall Mean	Policy Mean	Support Mean	Educator Mean	Academic Mean	Internati-onal mean
B15	Support children to use technology in the classroom in meaningful and appropriate ways	4.2	4.3	3.7	4.5	4.5	4
C9	Knowledge and experience of using digital technologies creatively	4	3.6	3.5	4	4.8	5
C20	Adequately assess and use appropriate technology.	4.1	3.7	3.8	4.5	4.5	4.5

Table 5.17. Comparison of Expert Opinion pertaining to Technology use in EC

The results of the study were somewhat limited when it came to identifying STEM or individual discipline content knowledge suitable for EC. **Table 5.18** groups statements that broadly relate to knowledge of STEM concepts, content, or definitions. While the overall mean for each statement is the same, this table demonstrates that a variety of opinions are held by the panel. None of the statements in this table reached consensus, but when international expert responses are viewed separately it is evident that all four statements were viewed favourably, with similar responses from the academic cohort.

	Sample Grouped Statements STEM content knowledge	Overall Mean	Policy Mean	Support Mean	Educator Mean	Academic Mean	International Mean
B18	Be informed about EC STEM. Possess good knowledge content areas and concepts for each discipline. Confident to introduce support EC STEM.	4.2	4.3	4.3	4.5	5	5
B19	Be aware of progression in STEM concepts and processes. Have the ability to use these in integrated, and in single-disciplinary ways.	4.2	4	3.8	4	4.8	5
C1	STEM content knowledge (e.g., shape, space, and number in mathematics; living things, habitats or forces in science).	4.2	4	4	4.5	4.5	5
C2	What is meant by EC STEM; definitions and core ideas from each STEM discipline that are appropriate for EC.	4.2	4	4.3	4	4.5	4

Table 5.18. Comparison of Expert Opinion pertaining to STEM content knowledge

Government oversight was not viewed positively. This perspective was demonstrated by the wider group in a number of statement responses and appeared in some open-ended comments across all three rounds. In round one a quarter of the expert panel expressed concerns about the use of the term ‘monitored’ when referring to EC educators’ professional development. This language was changed in round 2 questionnaire from “How should EC professionals be monitored and supported once early childhood STEM professional development is complete?” to “How should EC professionals be supported once early childhood STEM professional development is complete?” to reflect panellist feedback. **Table 5.19** provides an overview of statements that are relevant to government oversight. None of the statements in table 5.19 reached consensus in the final round. The overall scores are quite low but reviewing single cohort responses demonstrates that these statements were reviewed favourably by educators. In contrast, academics rated these questions poorly.

Once again, it should be acknowledged that the participant sample was small (15) and when divided further into expert cohorts' numbers were as low as two. While dissent between the groups is interesting, inferences cannot be universally applied.

	Sample Grouped Statements – Government Oversight	**Overall Mean**	**Policy Mean**	**Support Mean**	**Educator Mean**	**Academic Mean**	**International Mean**
D20	Government Departments to collaborate and take responsibility for the content of early childhood STEM professional development	3.8	4.3	4.3	4	2.8	3.5
D21	Creation of an early Childhood STEM Inter-Departmental group. Division of roles and responsibilities including rollout and evaluation of national early childhood STEM professional development	3.9	4	4.3	4.5	3.3	4
D22	Agreement by experts on early childhood STEM skills and knowledge requirements. Content of early childhood STEM professional development to be aligned with these requirements	3.8	4	4.3	5	3.5	4
D23	Assessment of current capacity in relation to early childhood STEM, including but not limited to; sector-wide survey; review of education inspection reports in relation to early childhood STEM; creation of an early childhood STEM expert panel	3.8	3.7	4.3	4.5	3.3	3.5
D31	Supportive STEM-informed Inspection from Tusla (The Child and Family Agency responsible for improving wellbeing and outcomes for children) and Department of Education Inspectorate	3.8	4.3	4	4	3	3.5

Table 5.19. Responses to statements regarding government oversight

5.4.4 Outlier Analysis

Outliers can have a significant effect on statistical variables, and it is common therefore to identify and eliminate outliers to check whether they have had an undue effect on group consensus (Beiderbeck et al. 2021). A number of checks were carried out where an individual's responses were out of the norm i.e. systematic low scoring of statements throughout. For example, one expert was vocal about the neoliberal of overtones suggested by mandatory EC STEM professional development and support. This expert chose not to complete sections related to professional- and system-wide support in round 2 but did complete this section in round 3. She questioned the language and positioning of some of the statements, for example:

> *Aligning professional development to a set of required skills, government departments taking responsibility for STEM. evaluation etc. reflects a neoliberalist perspective. The inclusion of STEM should not be a requirement from outside departments/agencies. STEM should be included because professionals 'want to' not because they 'have to'. (E2)*

As such, this expert's data was removed from these sections in round 3 and the statistical data analysed again to identify whether it had any significant effect. Interpreting the data however showed no impact on overall results.

5.5 Conclusion

The results of this study indicate that EC professionals continue to believe that EC STEM is 'not the core business of ECE' (Fleer, 2021). The overall impression the study communicates is that EC STEM remains an 'add on' and is not yet seen as a central element of ECE. ROI policy and curriculum change has made the provision of EC STEM a requirement, but even highly educated and experienced educators are unaware of their responsibilities in supporting EC STEM or inspection requirements concerning its enactment (O'Neill et al., 2023). Further early indications regarding Ireland's forthcoming ECE policy including an updated National Curriculum framework for EC (NCCA, 2009), a new literacy, numeracy, and digital literacy strategy (DES, 2023a, Dwyer et al. 2022) and the continued publication of STEM Education Policy implementation plans (DES, 2023b) suggest that STEM will become core to education policy in the coming years. This study therefore contributes to an emerging understanding of EC STEM and the needs of those tasked with its delivery in ROI. The next chapter presents the conclusions and final key recommendations from the research.

Chapter 6

Conclusions

Chapter 6 - Conclusions

6.1 Introduction

The final chapter reflects the overall research process and chosen methodology as they relate to the aims and purpose of the thesis. A summary of research findings, research recommendations and implications for policy and practice are addressed.

The aim of the study was to explore current conceptualisation of EC STEM and to gather expert opinion about how it should be defined and implemented in the Republic of Ireland (ROI). In response to a barrage of STEM education policies aimed at EC and beyond, I argued that guidance defining EC STEM and suggestions for its implementation from a policy level, was required. To cast a wide net and gather opinions from multiple jurisdictions, consultation with stakeholders from all points on the education continuum within the ROI and beyond was important. The findings are based on a three-round Delphi process that took place in 2023. 15 experts from 4 countries contributed to the study and their final responses were analysed using 'reflexive thematic analysis' (Braun & Clarke, 2022).

The purpose of this chapter is to explain the findings further, identify inferences for additional research or for praxis, provide a comprehensive response to the primary research questions, propose a rich set of recommendations, and describe the original contribution to knowledge that this study offers.

6.2 Summary of Findings

This study aimed to reach consensus on the integration of STEM in ECEC settings in the Republic of Ireland. Four sub-questions were identified in order to provide a comprehensive road map for implementation and supporting the implementation of EC STEM. The summary will be structured addressing each of these sub questions in turn.

6.2.1 How is EC STEM defined and understood?

The definition of EC STEM agreed by the panel refers not only to the full range of STEM disciplines but implies a certain pedagogical approach when implementing STEM in practice. The conceptualisation of EC STEM that emerged in this study is a flexible one, encompassing subject content and pedagogical elements. Mirroring existing research (Campbell & Speldewinde, 2022) the term 'STEM' was found to include some or all of STEM's constituent disciplines *and* refer to the development of children's inquiry skills and thinking capabilities. It is identified loosely as any activity, routine or discussion involving an individual STEM discipline, or any combination of these disciplines. Much like the relationship between numeracy and mathematics, findings suggest that the *application* of the STEM knowledge in everyday contexts and during child-led play episodes is particularly important in early childhood. This was expressed strongly and consistently across Delphi rounds and sections of the Delphi questionnaire.

Safeguarding of EC tradition was a central concern for the majority of panellists. As well as a clear agenda to protect and promote the use of active learning, play, curiosity, creativity and imagination, curriculum planning that followed children's emergent interests, and used their real-life questions as starting points, were deemed as crucial for EC STEM. Rather than a focus on content knowledge or the accumulation of facts in relation to science, technology, engineering and maths, the expert panel proposed a focus on a wider range of intellectual and thinking skills to frame STEM in EC, for example, exploration, investigation, and critical thinking. In addition, it was found that EC STEM experiences should be reflective of children's surroundings and everyday lives and the use of everyday activities, resources and the outdoors were valued. Overall, the study highlighted that some aspects of ECE pedagogy and curriculum are immovable and should not change with the introduction or implementation of EC STEM. Instead, the way in which EC STEM is conceptualised should adapt to the fundamental elements of ECE.

Integrated STEM was favoured in this study. A number of overlapping and interdependent reasons were provided by way of explanation including 1) STEM is most likely to be integrated in children's 'natural'/ child-led play and is therefore most fitting for this age group, 2) the holistic nature of EC pedagogy and play-based curricula lend themselves well to the integration of STEM subjects, 3) separate and subject-based STEM experiences are conflated with prescriptive approaches, which are deemed unsuitable in ECE, and finally, 4) that structured and adult led approaches are met with suspicion as schoolification, and formalisation of the sector is an ongoing concern. The promotion of integrated STEM found in this study differs somewhat from the existing literature. A recent scoping review established that different views and definitions of STEM continue to be evident across ECE studies, but that very few explicitly describe the integration of the four STEM disciplines (Macdonald et al., 2024). This is therefore a point that may require further investigation and analysis. It is worth noting that while the group advocated for integrated learning, they also stated that it was not necessary for all STEM subjects to be included in EC practice and advised that STEM be supported as children's interest arose. This, again, highlights the fact that STEM is not considered as wholly necessary in ECE.

Interestingly, and to the contrary of much of the existing literature (Wan et al., 2021; Johnston et al., 2022), the Arts were not deemed as necessary to an EC STEM definition. The term *EC STEM* was preferred over *EC STEAM*. However, the panel espoused that some level of creativity and control within the STEM experience was crucial for children, and the inclusion of play, creativity and curiosity are needed to underpin any EC STEM definition. That being the case, this could provide an explanation for the popularity of the term STEAM in ECEC and highlight a misunderstanding or lack of appreciation for the distinction between 'the Arts' and 'creativity'. Again, this point warrants further investigation.

6.2.3 Knowledge and dispositions ECEC educators require to support EC STEM?

The answer to this research question was not fully realised, and it is still unclear what knowledge, or skills might be required to meaningfully support EC STEM. Findings indicate that the general skills, knowledge, and dispositions that ECEC educators would be expected to possess were identified as significant. For example, the statements, *Strong, meaningful, and trusting relationships with children; Happy to be with children;* and *Find pleasure in their work,* all reached consensus. This suggests that educators do *not* need to upskill to be able to support EC STEM. Many similarly generic statements were agreed, but those that focused on more discrete STEM knowledge, concepts or methods were found unnecessary.

Noted in the findings was a lack of consensus on some of the statements in this area indicating that beliefs about the ideal level of discrete STEM knowledge or skills required, may still exist on a continuum. Those in academic positions or who are currently undertaking further study with a STEM lens were resolute about particular elements being included, [for example, maths talk, the language of STEM] and were dismayed that statements they were adamant about, were not agreed. This position was noted in a number of Delphi sections. In my experience as an EC STEM lecturer, and demonstrated more generally in the literature, confidence in one's ability can, at times, be attributed to a lack of knowledge about a certain topic (Kruger & Dunning, 1999). Some expert responses were detailed in the types of STEM skills and knowledge children should be supported to develop, and the associated need for educators to understand, identify and plan to support and extend these. However, these individuals were outliers; their opinions were strong and subject based, normally relating to their own subject or research expertise.

Research suggests that even highly qualified and experienced EC educators have engaged with very little STEM content in their careers and education to date (O'Neill et al., 2023). However, contrary to this point, the same educators report a high level of confidence and self-efficacy in supporting STEM in EC settings. As part of my own learning journey, I've come to realise how much there is to know about STEM as a subject, to say nothing of the breadth and depth of knowledge pertaining to each of its individual disciplines. Paradoxically, the more I understand the topic, the greater my appreciation of my limited knowledge. Accordingly, a lack of knowledge about a particular topic can prevent individuals from recognising the limitations of their abilities or understanding (Kruger & Dunning, 1999). I propose that this is a factor at play in this study. Some expert panel members do not have an EC or STEM background, but their expertise lies in another relevant field such as policy or curriculum development. Others who have a vast knowledge of ECE nationally or internationally, may be unfamiliar with the features of STEM education. This, I argue, may go some way toward explaining why there was a lack of agreement in this section. In the future, the findings of this study that highlight the crucial features of STEM and their overlap with ECE may provide some guidance and support understanding of EC STEM.

What the findings indicate is that the mediating role of the adult is crucial for learning; it is active, invested and can foster or amplify interests and learning. The adult role in EC STEM is similarly intricate where educators act as play partners, co-constructors of knowledge, co-learners, and collaborators, where children and adults are positioned as equals. Findings from this study position the adult in an active and intentional role in supporting EC STEM and found that a thin line is tread between partnering and supporting children during their STEM activity and taking over. The adult role is conceived of as that of a facilitator, partner, and co-constructor who provides support and guidance, while respecting children's ideas, initiations, and direction. Simultaneously, the adult role in noticing, recognising, and planning for STEM learning opportunities as part of an emergent curriculum was acknowledged. Prompts and provocations, modelling, demonstrating curiosity, and using wonder to invite children on STEM journeys are the methods proposed to support EC STEM in this study. I argue that this role is somewhat contradictory or at least difficult to define. This view requires a tightrope walk that even a very confident and knowledgeable educator may find daunting.

While an understanding of the critical role of the adult is evident, there is a hesitancy in agreeing to a more directive, formal or intentional function or responsibility. Some of this could be attributed to historical aspects of ECE or underpinning theory, such as Piaget's theory of cognitive development, and the positioning of the adult as a caring helper rather than educator. I argue that the findings of this study prop up Vygotskyian approaches, where adults play an active role as a 'skilled partner'. This is in line with other EC STEM research which recognises that some forms of knowledge require explicit teaching, but with the caveat that this should not disrupt or displace play (Fleer, 2010). It is possible for EC educators to use play-based pedagogy *and* intentionally teach specific STEM concepts (Thomas et al., 2011), but how this is achieved, especially in an Irish context, is still elusive.

6.2.4 Enhancing capacity through professional development opportunities.

How to enhance educators' capacity pertaining to STEM was a key research question in the study as it was envisaged answers here could provide guidance about what type of policy supports or professional development and training opportunities should be provided if an EC STEM requirement is maintained in ROI ECE. I have merged the final sub-questions [How could / should educator capacity in relation to EC STEM be enhanced? What professional development opportunities do educators need to meaningfully implement STEM in ECEC settings?] together to discover how educator capacity in relation to EC STEM can be enhanced and the professional development opportunities educators need to meaningfully implement STEM in ECEC settings.

There were limited but useful findings pertaining to suitable professional development and training opportunities for ECE professionals. In terms of PD content, findings indicate that play-based and integrated examples of STEM would be most useful. Learning outcomes should include the ability to 1) notice STEM already present in the daily routine, activities, and curriculum and, 2) name what STEM looks like in their practice [implying that this is different in each setting]. It was specified that in the facilitation of PD, hands-on experiences with STEM materials and processes, and time for examination of STEM practice, reflection and discussion should be included. This aligns with previous recommendations from the literature that EC STEM PD and ITE include time to interrogate and reflect on the impact of preconceived ideas, beliefs, and attitudes (Ring et al, 2017; Pacini-Ketchabaw, 2022). Further, incentives and supportive conditions should be built in, for example, provision of replacement staff to release educators for training, time in lieu or paying staff to attend training, and scheduling PD during work hours.

Very few agreements were made relating to system-wide support and requirements to up-scale any PD plans. The one statement that reached consensus was an interesting one. It reads ‘Establish broader coalitions that enable multiple stakeholders to learn together and create a shared language and understanding i.e., educators, academics, mentors, inspectorate, curriculum bodies and EC policy makers.’ While in and of itself this statement appears innocuous, when considered alongside open-ended responses, statements that did not reach consensus in this section, and a poor history of consultation with ECE stakeholders in ROI, it insinuates a desire for greater control and influence. Compared to later stages of education, EC stakeholders have few mechanisms to influence policy or respond to issues that arise due to new policy requirements or conditions.

The lack of consensus here indicates a sense of frustration that has gone unchecked for decades. The need to work *with* the sector to create buy-in, draw on expertise and overcome issues unique to the ECEC were evident in the literature (Hayes & Duignan, 2017; Hayes & Urban, 2018; McCormilla, 2018) and may lead to a more appropriate PD response for the varied professional profiles of the ECEC sector in Ireland (Government of Ireland, 2023; O’Neill et al., 2022, 2024). This is an important point when considering ongoing EC STEM plans in the ROI.

Out of 32 statements in the Delphi questionnaire that relate to professional development and sector-wide support, only 7 reached any sort of consensus (3 strong consensus and 4 consensus). This was the only section of the Delphi in which the level of consensus dropped steadily as the study progressed. I have found it difficult to account for this, but the historical divides that define the EC sector in ROI may shed some light. Support and professional development in EC in Ireland has always been problematic. Some of this is down to a poor track record. EC policy is often implemented in a piecemeal fashion without appropriate levels of funding (see NCCA, 2013; GOI, 2018; French, 2013; Walshe, 2024; OECD, 2021e for details). More worryingly, results indicate that even if there was a clear agreement about how EC STEM should be enacted in ROI, the panel lacked confidence in the government to implement and resource this in a meaningful way. In 2024, stakeholders continue to call on the state to establish a coordinated and systematic implementation plan to underpin the provision of quality ECE (Walshe, 2024), let alone support for EC STEM alone. Emphasising this point one expert stated 'STEM is important, but it must be supported in the context of developing the whole child. The update of Aistear [the early childhood curriculum framework in ROI] provides support for STEM within the context of the whole child and it is this I think the focus should be on for CPD.'

6.3 Contribution to Knowledge

This study offers a unique contribution to our emerging understanding of STEM in early childhood settings. Findings here provide greater insight into how EC STEM is defined, conceptualised, and how EC STEM differs from understandings of STEM in other parts of the education system. The policy lens used to frame the study presents a unique perspective, one that could be used to counter or support arguments for the introduction of STEM in early childhood. I assert this is one of very few studies using this angle to explore the implementation of STEM, and due to the increase in EC STEM research and policy (MacDonald, 2024, Wan et al, 2021, Johnston et al., 2022), it is one that is much needed. As Lovatt (2020) suggests, the political focus on STEM is concentrated on the outcomes of a STEM education and less attention is paid on how to define, teach, or learn about it. For this reason, exploration of these ideas has considerable value in an area of research that is still evolving.

This study strongly indicates that understandings of STEM are emerging and that it may take some time for consensus to be achieved fully, especially since the very idea of STEM in EC seems to be of concern. I note that for many, the implied *meaning* behind its adoption is troublesome, as STEM is often conflated with formal and directive teaching. This issue has been identified previously (Fosse et al, 2018; Pyle & Daniels, 2017; O'Síoráin et al, 2023) and this study strengthens this position by adding to existing literature on this topic. It bolsters the idea that STEM education policy needs to take a gentle approach and clearly acknowledge ECE pedagogy and tradition and address how this can be safeguarded.

Further, this research identified the complex and often contradictory role that the adult occupies when supporting EC STEM. In the Republic of Ireland, and elsewhere, the EC profession has experienced unparalleled levels of change in preceding years. Many educators are struggling to re-imagine their professional position and adapt to new and evermore complex demands placed on them by policy agendas. This study provides contemporary evidence that the role of the adult in EC remains difficult to define. While active engagement with the child, environment and curriculum is expected, adult-led 'teaching' is still met with caution. This caution is even more exacting when examining STEM which is linked to formality, teaching and considered more appropriate for older cohorts of children.

6.4 Study Implications

This study provides a clear explanation of EC STEM. Findings detail that an EC STEM definition is somewhat flexible relating to both practice approaches and content and can refer to any STEM discipline alone or in combination with others. While EC STEM is connected to the STEM defined in later years of education, it should be considered as separate and distinct with its own traditions and influences. This point alone has implications for research, policy, and praxis.

The findings support an understanding of how PD should be structured, and the type of training approaches used to be most impactful; clearer definitions lead to greater understanding of core element of EC and how this differs to other conceptualisations of STEM; and identifying the elements considered crucial to respect EC traditions can be used to create buy-in and cooperation from the sector. As such, findings from the study will be useful for a number of stakeholders including EC STEM Policy and curriculum developers, those in training and support positions, ECE researchers, academics, and lecturers, and long-term may provide benefits for children in EC settings supported to engage with STEM.

In terms of potential impact of the study in the ROI, findings can be used to influence forthcoming ECE policy. A swathe of new and /or updated ECE policy documents are expected in the coming year or two (2024-2026). As STEM is a relatively new concept in EC, having more detail about current conceptualisations of EC STEM, its application to EC settings and potential issues that may arise with its implementation, would be valuable. The details in this study can support policy makers to make more informed decisions about EC STEM by indicating what is needed to be in place for policy success. EC STEM definitions and core elements agreed can be used in updated curriculum and strategy documents to provide a more streamlined and consistent approach. In addition, the need to include and consult with ECE stakeholders in ROI was evident in findings. This study strengthens existing plans to use communities of practice as PD support for EC STEM (Government of Ireland, 2023). Communities of practice (COP) have the potential to enable meaningful and practical enactment of STEM as they can be tailored to the needs of the group whether that be by role (educator, manager, mentor, inspector), geographical location (urban, rural, designated area of disadvantage), age range of children (provision for babies, toddlers, young children, school-aged childcare) or discipline interest (science, technology, engineering, mathematics). There are already a number of EC STEM groups working in this way including academic special interest groups, City and County Childcare Committee COPs and a EC STEAM network who offers support for educators, managers, researchers, academics and those in mentoring roles. This approach would also facilitate buy-in from the sector by providing opportunities for feedback, discussion, and exploration about topics and ideas relevant to each person and their role. If recommendations made here to include professionals across the education spectrum i.e. educators, trainers, mentors, researchers, inspection, and curriculum development, are followed it would allow for a greater transfer of knowledge. Allowing a combined bottom-up and top-down mechanism for sharing ideas and creating meaningful support and implementation.

Further afield, the findings of this study will add to ongoing debates about EC STEM and reinforce some of the ideas emerging from the southern hemisphere (for example definitions of STEM aligning with Speldewinde and Campbell, 2022, 2023; Campbell et al, 2018). The data and findings from this study could form the basis of comparative research pertaining to STEM to explore the policy environment and context on STEM implementation. Finding here will also add to ongoing debate about the intentional role of the adult and how it has yet to be resolved.

6.5 Reflections and Limitations

Research is a decision-making process that will never be perfect (Thompson, 2021). This section will identify study limitations and summarise suggestions for improvement pertaining to general study design and a more focused consideration of the Delphi procedure itself. Having reflected on the overall process, I identify the areas that could have been improved or adapted to better answer the research questions. Choices, impact, and remedy are outlined. Recommendations regarding the use of Delphi in ECE research contexts and study limitations round off this section.

Study limitations include the small cohort of participants involved (15) with a wide variety of expertise. Focus on one jurisdiction and using a policy lens make the findings less generalisable for the international ECE community as they are situated within the ROI ECE sector. Ireland is a small country with a specific set of historical and political shortcomings in relation to ECE that undoubtedly impact attitudes. This suggests that other jurisdictions might generate alternative findings answering the same research question. The expert panel was structured to include a variety of stakeholders, allow for attrition, and to maintain equal numbers in each cohort throughout the Delphi procedure. The selection criteria for experts included the need for each panellist to be in an existing role in education, policy, inspection or support in ROI, which limited the sample. As a result, the experts were a homogenous group with the vast majority Caucasian and identifying as female. On reflection, the inclusion of a greater number of international experts from both the northern and southern hemisphere may have been useful in involving a wider demographic and challenging perceptions of the ROI cohort. Considering concerns about STEM and the intersectionality of race, gender and class including a more varied cohort of experts would strengthen the findings of the Delphi study. This is especially true as findings suggest that there is a wider chasm between ROI and international experts than between other expert cohorts.

The lack of agreement in sections of the questionnaire pertaining to support and PD leads me to question whether the type of questions or the way in which they were presented contributed to the lack of consensus. Beiderbeck et al. (2021) suggest that this can highlight a systemic misunderstanding of the intent behind the questions and or the comprehensibility of the statements.

The Delphi procedure is not a step-by-step list of instructions, but a framework for eliciting expert opinion. The researcher chooses from a series of flexible characteristics that best fit the research questions. However, each decision has an impact on the outcomes of the study. Choices made as part of the study design impacted the overall success of the Delphi procedure. The following paragraphs highlight some of the decisions made, their impact on study outcomes and how, in future, this could be remedied.

When designing round 2 and 3 questionnaires, a Likert scale of 1 to 5 was adopted. As the study progressed it became evident that this number was insufficient and did not adequately recognise opinions that may have been on the fence. If one expert rated a statement as ‘somewhat important’ (position 3 on the scale) or ‘neutral’ (position 2 on the scale), no consensus is reached even if every other expert deemed it essential. I recommend therefore that a seven-point scale, as used in the original study (Dalkey & Helmer, 1963) would be appropriate. Further, the addition of a 'not sure' or 'don't know' option would allow experts to express unresolved positions clearly.

The classic Delphi procedure, used in this study, consists of three rounds with detailed feedback between each round (Iqbal & Pippon-Young, 2009). There were significant shifts in opinion from round 2 to 3, and an additional round, or gathering open-ended feedback from the group based on the final report, may have conveyed more change without leading to further expert burn-out or attrition. Detailed feedback was provided to the expert panel between rounds (see methods chapter for detail). While changes were made to statements based on expert feedback this was limited in number (3 total). In hindsight, the addition of statements of dissent i.e. where people strongly disagreed with consensus, should have been added as statements to the next round, testing stability and reflecting expert dissent more precisely.

Weighing up the number of generic statements that were included in round 2 and 3 (especially in section 3, knowledge, pedagogy, and disposition) a choice to exclude general statements / ideas would have been more effective in answering research questions. Further, responses would be more accurate had some statements be divided into smaller parts to ensure that consensus was being reached on all elements of a statement, rather than just one or two. For example, statement B18 'Be informed about EC STEM. Possess good knowledge of content areas and concepts for each discipline. Confidence to introduce support EC STEM', should have been divided into three separate statements to improve validity of results.

The findings of this study, especially concerning PD and wider sector supports, are situated within the ROI ECE sector. Ireland is a small country with a specific set of historical and political shortcomings in relation to ECE that undoubtedly impact attitudes. This suggests that other jurisdictions might generate alternative findings answering the same research question. As such, comparative research would demonstrate common themes and reinforce the validity of findings.

6.6 Research Recommendations

EC STEM is a reasonably new research area requiring further study (Johnston et al., 2022; Wan et al., 2021). This study revealed that conceptualisations of EC STEM and the role of the educator and other EC professionals within that are complex. A wide range of opinions are evident and differences between expert cohorts could suggest that experience, background, education, and location influence how opinions about EC STEM are formed. The study design and methodology employed facilitated the review of personal responses and statistical data that were valuable in developing an understanding of the ecosystem in which EC STEM is enacted. The Delphi method demonstrated that initial responses gleaned through research may not be entirely accurate and that expert judgement does change with the introduction of more information and having more time to consider pertinent factors.

Overall, the study highlighted that some aspects of ECE pedagogy and curriculum are immovable and should not change with the introduction or implementation of EC STEM. Instead, the way in which EC STEM is conceptualised should adapt to the fundamental elements of ECE. Consistent with previous literature (for example, Barblett et al., 2016; Fosse et al., 2018; O'Neill, 2021b; O'Síoráin et al., 2023; Schriever et al., 2020; van Oers, 2013) opposition to certain ideas, such as the intentionality of the educator, the use of technology in ECE, and STEM content knowledge for educators, indicates further research into each of these topics is required. An uncertainty was evident, as agreements in one section were contradicted in another. Bearing in mind that study participants were experts, this uncertainty is unsettling and demonstrates the unlikely enactment of EC STEM in ROI.

In order for all children to have access to EC STEM experiences, educators need to be well-prepared in both STEM content and pedagogy (Early Childhood STEM Working Group, 2017). Findings of this study suggest that the exact content knowledge and, to a lesser extent, pedagogical approaches required by educators are yet to be identified with any certainty. Practice based research investigating how educators support EC STEM, and classifying the knowledge and pedagogical approaches observed would be a valuable addition to literature in this field. Ethnographic study of children's STEM learning in practice could showcase how STEM is supported in everyday practice.

In relation to the ROI ECE sector, I argue that a clear vision for EC STEM supports, and uniform conceptualisation of what EC STEM should be in ROI are necessary starting points if this policy position is to continue. I maintain that the inclusion of EC in STEM education policy and inspection criteria in Ireland is premature. Systems are not in place at any level to ensure a comprehensive and meaningful use of EC STEM and it is likely that what is done will be done badly and demotivate an already reeling sector. Better to remove the requirement until after advancements have been made. Otherwise, what does it achieve without a clear research base, plan, or support.

6.7 Conclusion

This thesis has sought to contribute to the ongoing research and practice conversation related to EC STEM. Policy demands continue to evolve and ever-increasing expectations are placed on educators. The thesis has made visible ways in which education policy can be premature, placing undue demands on educators and the profession as a whole, before research and understanding is comprehensive enough for actions to be meaningfully enacted. This study has made some progress in defining EC STEM, identifying elements that are critical to its conceptualisation and distinguishing how this differs from other forms of STEM/ STEAM.

The purpose of this study was to investigate how EC STEM could be enacted in ROI, but I've concluded that this investigation is untimely. An acceptance of the usefulness and appropriateness of EC STEM is still emerging even among this expert cohort. The lack of agreement about how this may be supported is a demonstration of a bigger problem within the EC sector in ROI. Until other issues are addressed, or a comprehensive PD plan is put in place that supports professionals where they are at, the inclusion of STEM in EC inspection tools and policy is premature.

Appendices

Appendices

Appendix 1: Pilot Questionnaire

DELPHI TEST QUESTIONNAIRE

Q1 I have read and understood the project information sheet dated April 2023 or the project has been fully explained to me. (If you will answer No to this question please do not proceed with this consent form until you are fully aware of what your participation in the project will mean.)

○ Yes (1)

○ No (2)

Q2 I have been given the opportunity to ask questions about the project.

○ Yes (1)

○ No (2)

Q3 I agree to take part in the project. I understand that taking part in the project will include the completion of three questionnaires over the course of 3-4 months

○ Yes (1)

○ No (2)

Q4 I understand that by choosing to participate as a volunteer in this research, this does not create a legally binding agreement nor is it intended to create an employment relationship with the University of Sheffield.

○ Yes (1)

○ No (2)

Q5 I understand that my taking part is voluntary and that I can withdraw from the study at any time. I understand that once the first questionnaire has been submitted this data cannot be withdrawn from the project but that I can withdraw from any on-going or future data collection; I do not have to give any reasons for why I no longer want to take part and there will be no adverse consequences if I choose to withdraw.

○ Yes (1)

○ No (2)

Q6 I understand my personal details such as name, phone number and email address etc. will not be revealed to people outside the project.

○ Yes (1)

○ No (2)

Q7 I understand and agree that my words may be quoted in publications, reports, web pages, and other research outputs. I understand that I will not be named in these outputs unless I specifically request this.

○ Yes (1)

○ No (2)

Q8 I understand and agree that ED Supervisors from the University of Sheffield will have access to this data in an pseudonymised format only if they agree to preserve the confidentiality of the information as requested in this form.

○ Yes (1)

○ No (2)

Q9 I understand and agree that other authorised researchers may use my data in publications, reports, web pages, and other research outputs, only if they agree to preserve the confidentiality of the information as requested in this form. I understand that I will be asked to provide explicit consent for use of data in other publications

○ Yes (1)

○ No (2)

Q10 I agree to assign the copyright I hold in any materials generated as part of this project to The University of Sheffield.

◯ Yes (1)

◯ No (2)

A brief note about the language in this questionnaire

- For clarity, the term STEM is used throughout the questionnaire. This does not denote a preference for this term over others, or preclude the importance of STEAM or integrated STEM.

- Similarly, the term professional development is meant in the broadest terms and includes initial education, short courses and professional development programmes

- The term early childhood professional refers to anyone working in early childhood and education and care including early childhood students, early childhood educators, early childhood setting managers, early childhood researchers, and those in early childhood policy, support and inspection roles.

Thank you for taking the time to complete this questionnaire

Section 1 – Background information about the expert

Q11 Please outline your role and the age range it has been primarily focused on. (i.e. research, policy or teaching role; birth-3 years, 3-6 years, adult education; focus on Science, Technology, Engineering, Mathematics, STEM).

Q12 Where relevant, please outline the nature of STEM professional development programmes that you have led, or been involved in (i.e. participant profile, delivery and training methods, STEM or individual discipline focus)

Q13 Have you had any direct experience with a STEM professional development? (i.e. with preparation of professional development materials or with facilitating STEM professional development?) If so, please outline the nature of this experience

Q14 What **broad characteristics**, particularly in terms of theoretical components and practical skills, do you consider to be important for early childhood professionals working in the field of early childhood STEM?

Section 2 – Defining STEM

Q15 What **essential elements** are required to be included in any definition of early childhood STEM?

Q16 What **discipline content areas** (i.e. science, technology, engineering, mathematics, the arts) are required as effective components of an early childhood STEM definition?

Q17 What **pedagogical approaches** are required as effective components of an early childhood STEM definition?

Q18 How should / should **the arts** be included in any definition of early childhood STEM?

Section 3 – Early childhood education and STEM

Q19 What **aspects of early childhood education** (i.e. holistic development, play-based approaches, active learning) need to be reflected in early childhood STEM, in order for it to be accepted by the sector?

Q20 What is the **role or function** of the early childhood professional in supporting early childhood STEM?

Q21 What are **the benefits** for children who engage in early childhood STEM?

Q39 What **steps are required** to overcome resistance to EC STEM, should it arise?

Section 4 - Essential STEM Elements

Q22 What **essential skills** do early childhood professionals require as components of early childhood STEM professional development?

Q23 What **essential knowledge** do early childhood professionals require as components of an early childhood STEM professional development?

Q24 What **essential attitudes, qualities and attributes** do early childhood professionals require to support early childhood STEM professional development?

Q25 What **essential pedagogical approaches** do early childhood professionals require to support early childhood STEM professional development?

Section 5 - Professional Development

Q26 In your opinion what are the most **effective methods** of organising and facilitating early childhood STEM professional development?

Q27 What is the **minimum period of participation** desirable for early childhood STEM professional development?

Q28 What **materials or resources** should be used to support early childhood STEM professional development?

Q29 What **STEM processes** should be experienced to support early childhood STEM professional development?

Q30 How should EC professionals be **monitored and supported** when early childhood STEM professional development is complete

Section 6: Sector-wide supports

Q31 Who should be responsible for **administering, facilitating and monitoring** early childhood STEM professional development?

Q32 What **features of organisation** at different levels need to be in place to scale up early childhood STEM professional development?

Q33 What are your recommendations for **key steps** in the process of scaling up early childhood STEM professional development?

Q34 Are there any other suggestions / comments you would like to make about early childhood STEM

Appendix 2: Expert panel invite and follow up email.

Reaching consensus on the provision of Science Technology Engineering and Mathematics (STEM) in Early Childhood

Project Title: Reaching consensus on the provision of STEM in ECEC settings in the Republic of Ireland – A Delphi Study

Research Supervisors: Dr. Liz Chesworth and Dr. Lauren Powell, University of Sheffield

Dear,

I am writing to you as a leading global expert in the field of Early Childhood Education and Care (ECEC), to invite you to participate in an exploratory study of expert views regarding early childhood (EC) STEM.

I would like to gain your expert views and opinions on (i) defining STEM in ECEC (ii) practical skills to be included within this definition and (iii) appropriate professional development opportunities required to meaningfully implement STEM in ECEC settings

If you wish to take part in this study, I would ask for your time for three one-our sessions between April and June 2023. This can be online at your convenience.

For Further Information or to express an interest in taking part, please reply to this email

Follow up email:

Dear XXXX,

I am writing to you as a leading global expert in the field of Early Childhood Education and Care (ECEC), to invite you to participate in an exploratory study of expert views regarding early childhood (EC) STEM.
I'm really keen to gain your expert views and opinions and would love it if you would agree to take part. The study's success relies on participation from experts from outside the jurisdiction under investigation. Your input would be greatly appreciated and really add to the strength of the study. Please find an information sheet attached with further details about the study and the process involved.

For further information or to express an interest in taking part, please reply to this email
Looking forward to hearing from you
Sandra O'Neill

Appendix 3: Round 1 Questionnaire

Code name	Code Properties	Typical exemplars	Atypical exemplars
Early childhood pedagogy and approaches	Describing elements of early childhood education that should be reflected in EC STEM. Elements considered critical such as play, active learning, enquiry-based approaches, holistic learning and provision of opportunities to explore and problem solve.	Play and play-based approaches are key, holistic learning and development is crucial, hand-on experiential experiences are key. Playful STEM learning is important. Children need to be engaged in active, experiential, and hand-on investigations. This is about babies, toddlers and young children learning about the world around them so that they have opportunities to question, predict, while engaging in meaningful problem solving and testing. This happens best through open ended learning experiences. Play based active hands-on learning, setting up invitations to play where children are given the opportunities to explore and expand their thinking and creativity. I feel that using a play-based approach would be the best way to encourage educators to interact with STEM education, but children encounter STEM all throughout their lives, so this could also fall under holistic development.	fundamental understanding of the sciences concepts they are using and presenting to children…for example I use a lot of light and shadow in my teaching, which are scientific objects, the teacher for me don´t have to know the whole sciences behind but have an understanding to help children and be able to guide and develop children play, without controlling it. I sometimes think that teachers take over the play because they don´t trust that children will find things out of their own, or that they buy educational packages because they don´t trust their own way of doing.
Role or function of the early educator re EC STEM	General description of how the educators support EC STEM learning in the setting. Can include general descriptions of knowledge, self-efficacy, pedagogical approaches used.	I see the educator's role as being able to facilitate the learning, build on the children's interests and curiosity in STEM. Providing children with opportunities to explore STEM and resources that are age appropriate through their observations and curriculum planning. Educators can promote children's learning in STEM by providing children with opportunities to exercise their curiosity, to predict and experiment with an idea through multi-sensory, hands-on and open-ended play experiences. The educator can extend the children's explorations by noticing and naming the learning opportunities for STEM as they play, engage and explore with the children	To explicitly teach concepts like counting, life-cycles, how to use any tech that may exist in the class like cameras or radios, and to support parents to use maths-talk in the home and educate them on their crucial role in their child's mindset
Integration of subjects	Describing how STEM subject content be	In EC it's difficult to separate the disciplines as any practical activity for one of the disciplines (such as Engineering) with young children, will often contain aspects of Maths for example (such as measurement/number sense/space, etc.). The educator may have the primary	I do not believe we should be prescriptive/ advocate that STEM subjects be supported independently as this

	approached, planned and enacted in EC settings. Teaching in an integrated or subject-specific way.	intention of exploring a Science concept with children, but be aware that the emergence/consideration of other STEM disciplines concurrently, could enrich the learning. I feel that we regularly integrate these (STEM) without realising. Not every element of STEM needs to be present, but they often coexist and overlap. I feel that some elements of STEM could be supported independently (e.g., Counting is pure maths), but for a richer experience, a multidisciplinary approach should be fostered.	may have the potential to lead to a more directive teaching/learning style in EC.

DELPHI ROUND1 QUESTIONNAIRE

Welcome: Thank you for agreeing to take part in this study about Early Childhood Science, Technology, Engineering and Mathematics (STEM). There are 16 open-ended questions in total. Provide as much or as little detail as you see fit in your responses.

Section1: Informed Consent

Q2 I have read and understood the project information sheet dated April 2023 or the project has been fully explained to me (If you answer no to this question please do not proceed with until you are fully aware of what your participation in the project will mean.)

○ Yes (1)

○ No (2)

Q3 I have been given the opportunity to ask questions about the project.

○ Yes (1)

○ No (2)

Q4 I agree to take part in the project. I understand that taking part in the project will include the completion of three questionnaires over the course of 3-4 months

○ Yes (1)

○ No (2)

Q5 I understand that by choosing to participate as a volunteer in this research, this does not create a legally binding agreement nor is it intended to create an employment relationship with the University of Sheffield.

○ Yes (1)

◯ No (2)

Q6 I understand that my taking part is voluntary and that I can withdraw from the study at any time. I understand that once the first questionnaire has been submitted this data cannot be withdrawn from the project but that I can withdraw from any on-going or future data collection; I do not have to give any reasons for why I no longer want to take part and there will be no adverse consequences if I choose to withdraw.

◯ Yes (1)

◯ No (2)

Q7 I understand my personal details such as name, phone number and email address etc. will not be revealed to people outside the project.

◯ Yes (1)

◯ No (2)

Q8 I understand and agree that my words may be quoted in publications, reports, web pages, and other research outputs. I understand that I will not be named in these outputs unless I specifically request this.

◯ Yes (1)

◯ No (2)

Q9 I understand and agree that ED Supervisors from the University of Sheffield will have access to this data in an pseudonymised format only if they agree to preserve the confidentiality of the information as requested in this form.

◯ Yes (1)

◯ No (2)

Q10 I understand and agree that other authorised researchers may use my data in publications, reports, web pages, and other research outputs, only if they agree to preserve the confidentiality of the information as requested in this form. I understand that I will be asked to provide explicit consent for use of data in other publications

◯ Yes (1)

◯ No (2)

Q11 I agree to assign the copyright I hold in any materials generated as part of this project to The University of Sheffield.

◯ Yes (1)

◯ No (2)

A note about language

A brief note about the language in this questionnaire

For clarity, the term STEM (science, technology, engineering and mathematics) is used throughout the questionnaire. This does **not** denote a preference for this term over others, or preclude the importance of STEAM or integrated STEM.

Similarly, the term **professional development (PD)** is meant in the broadest terms and includes initial education, short courses and professional development programmes

The term early childhood professional refers to **anyone working in early childhood and education and care** including early childhood students, early childhood educators, early childhood setting managers, early childhood researchers, and those in early childhood policy, support and inspection roles.

Section 2: Participant profile

Q14 Please outline your role and the age range it has primarily focused on (i.e. research, policy or teaching role; birth-3 years, 3-6 years, adult education).

Q15 Please outline any experience you have with STEM (in practice, teaching, research or otherwise)

Q16 Have you had any direct experience with STEM professional development? If so, please outline the nature of this experience (i.e. participant profile, delivery and training methods, STEM or individual STEM discipline focus).

Section 3: Defining EC STEM

Q17 What essential elements are required to be included in any early childhood STEM definition (i.e. should science, technology, engineering **and** mathematics be included? Should the arts be included? In your opinion are there any other elements that should be included?)

Q18 How important is the **integration of subjects** in an early childhood STEM definition? (i.e. How many STEM subject areas are required to be present in order for an experience to be considered STEM? Does an experience focusing on science alone come under the banner of early childhood STEM? Can/ should STEM subjects be supported independently in early childhood?)

Section 4: Early Childhood Care and Education and STEM

Q19 What aspects of early childhood education (i.e. holistic development, play-based approaches, active learning) need to be reflected in early childhood STEM, in order for it to be accepted by the sector?

Q20 What is the role or function of the early childhood professional in supporting early childhood STEM?

Section 5: Essential EC STEM

Q21 What essential STEM **knowledge** do early childhood professionals require to successfully support early childhood STEM? (for example, a detailed knowledge of concepts related to science, technology, engineering and mathematics; A high level of digital literacy, knowledge of the arts)

Q22 What essential **pedagogical approaches**, if any, do early childhood professionals have to master to successfully support early childhood STEM? (for example, the engineering design process, the project approach, an ability to assess and ulitise technology to enhance and expand children's play)

Q23 What essential **attitudes and dispositions** do early childhood professionals require to successfully support early childhood STEM?

Section 6: STEM PD

Q25 In your opinion, what are the **most effective methods** of organising and facilitating early childhood STEM professional development?

Q26 What is the **minimum period of participation** desirable for early childhood STEM professional development?

Q27 How should EC professionals be **monitored and supported** once early childhood STEM professional development is complete?

Q28 Who should be **responsible for** administering, facilitating and monitoring early childhood STEM professional development?

Q29 What **features of organisation at different levels** need to be in place to scale up early childhood STEM professional development?

Comments or Suggestions

Q30 Are there any other suggestions / comments you would like to make about early childhood STEM at this time?

Appendix 4: Round 2 Questionnaire

Accompanying email:

Thank you for your timely and insightful completion of the second round of this Delphi study. I greatly appreciate your invaluable expertise, given the many competing demands on your time.

In round 3, the statements from round 2 are put to you again. This time you are provided with additional information (see the report attached to this email) including opinions and ratings from the other members of the expert panel. Please read the report before you complete the last questionnaire.

As before, you are strongly encouraged to add comments and explanations in the boxes provided. These will be reviewed and outlined in the final report.

I would be most grateful if you could complete the questionnaire by 20th October

I am enormously grateful for your expertise and time.

Sandra

DELPHI ROUND 2

Thank you for your timely and insightful completion of the first round of this Delphi study. I greatly appreciate your invaluable expertise, given the many competing demands on your time.

In round two, information from the last round has been collated and presented as a series of statements, grouped together under various headings. You will be asked to rate your level of agreement with each statement.

Reflecting the varied feedback from the expert panel, statements within each section include diverse and opposing ideas or, in some instances, are very similar with minor but distinct differences. For this reason, it is suggested that you **read all statements carefully** before rating your level of agreement

If you want to add a caveat to your answer, clarify a statement or suggest an edit, you can do this in the space provided after each statement. Edits and clarifications **are encouraged** and these additions will be incorporated into the next round.

Once the majority of the expert panel (80%+) express strong agreement with a statement, a consensus is reached. This statement is then considered to be a reflection of the panel's views (however, outliers will be recorded and discussed in the final report). If consensus is not reached in this round, edits and clarifications will be reviewed, and statements will be adapted for review in the final round.

In order to maintain my scheduled timeline I would be most grateful if you could complete the questionnaire by **Tuesday 20th June**.
I am enormously grateful for your expertise and time.
Sandra

Informed Consent

Q2 I have read and understood the project information sheet dated April 2023 or the project has been fully explained to me. (If you will answer No to this question please do not proceed with this consent form until you are fully aware of what your participation in the project will mean.)

○ Yes (1)

○ No (2)

Q3 I have been given the opportunity to ask questions about the project.

◯ Yes (1)

◯ No (2)

Q4 I agree to take part in the project. I understand that taking part in the project will include the completion of three questionnaires over the course of 3-4 months

◯ Yes (1)

◯ No (2)

Q5 I understand that by choosing to participate as a volunteer in this research, this does not create a legally binding agreement nor is it intended to create an employment relationship with the University of Sheffield.

◯ Yes (1)

◯ No (2)

Q6 I understand that my taking part is voluntary and that I can withdraw from the study at any time. I understand that once the first questionnaire has been submitted this data cannot be withdrawn from the project but that I can withdraw from any on-going or future data collection; I do not have to give any reasons for why I no longer want to take part and there will be no adverse consequences if I choose to withdraw.

◯ Yes (1)

◯ No (2)

Q7 I understand my personal details such as name, phone number and email address etc. will not be revealed to people outside the project.

◯ Yes (1)

◯ No (2)

Q8 I understand and agree that my words may be quoted in publications, reports, web pages, and other research outputs. I understand that I will not be named in these outputs unless I specifically request this.

○ Yes (1)

○ No (2)

Q9 I understand and agree that ED Supervisors from the University of Sheffield will have access to this data in an pseudonymised format only if they agree to preserve the confidentiality of the information as requested in this form.

○ Yes (1)

○ No (2)

Q10 I understand and agree that other authorised researchers may use my data in publications, reports, web pages, and other research outputs, only if they agree to preserve the confidentiality of the information as requested in this form. I understand that I will be asked to provide explicit consent for use of data in other publications

○ Yes (1)

○ No (2)

Q11 I agree to assign the copyright I hold in any materials generated as part of this project to The University of Sheffield.

○ Yes (1)

○ No (2)

Section 1. Defining Early Childhood STEM

Q13 The following items relate to **essential elements** of an Early Childhood STEM **definition**. Please rate the importance of each item

	Not important (1)	Neutral (2)	Somewhat Important (3)	Important (4)	Extremely Important (5)
Science, Technology, Engineering, Mathematics	○	○	○	○	○
the Arts	○	○	○	○	○
Innovation	○	○	○	○	○
Play	○	○	○	○	○
Curiosity	○	○	○	○	○
Creativity, imagination	○	○	○	○	○
Critical thinking	○	○	○	○	○
Language of STEM	○	○	○	○	○

Q14 If you want to add a caveat to answers, clarify a statement or suggest an edit to the answers above, you can do this in the space provided. Edits and clarifications are encouraged

Q15 The following statements relate to **the integration of subjects/ disciplines in early childhood STEM.** Please rate your level of agreement with each statement

	Disagree (1)	Neutral (2)	Somewhat Agree (3)	Agree (4)	Strongly Agree (5)
EC STEM is any experience, routine or discussion involving a STEM discipline (EITHER science, technology, engineering, math or a combination of these disciplines) (1)	○	○	○	○	○
STEM disciplines naturally coexist and overlap in EC settings. One or more STEM discipline can arise during play and/or routine activities. (2)	○	○	○	○	○
Young children do not learn in discrete categories or subject areas. However some discipline content knowledge can be supported independently (e.g. counting or measure in mathematics),	○	○	○	○	○
Exposure to the ways of thinking that characterise each of the subjects is equally important e.g. using a maths lens, engineering habits of mind (4)	○	○	○	○	○
STEM subjects taught alone could lead to more directive teaching style. Planned STEM activities are not required, and prescriptive approaches should be avoided (5)	○	○	○	○	○
The use of the project approach or long-term investigations supports integration of STEM subjects over time.	○	○	○	○	○
To support children's STEM learning, an equitable inclusion of all four disciplines should be provided in the course of the term/ year, and within the curriculum.	○	○	○	○	○

Integrated learning leads to a richer experience for children (8)	○	○	○	○	○

Q16 If you want to add a caveat to answers, clarify a statement or suggest an edit to the answers above, you can do this in the space provided. Edits and clarifications are encouraged

Section 2: Early Childhood Education and STEM

Q18 The following items relate to **elements of early childhood education to be included in EC STEM provision**. Please rate the importance of each item

	Not important (1)	Neutral (2)	Somewhat Important (3)	Important (4)	Extremely Important (5)
Play, active learning and hands-on experiences	○	○	○	○	○
Children's agency, child-led approaches, respecting children's freedom to make choices	○	○	○	○	○
The use of everyday, simple and open-ended materials. The use of the outdoors and nature	○	○	○	○	○
Emergent approaches. Building on children's interests. Using children's interests and funds of knowledge as starting points for investigations	○	○	○	○	○
Inquiry-based approaches including the use of projects and long term investigations (5)	○	○	○	○	○

The provision of play invitations and prompts to provoke inquiry and engage curiosity (6)	○	○	○	○	○
Co-construction of knowledge between adult and child (9)	○	○	○	○	○
Slow pedagogy (10)	○	○	○	○	○
Provision of opportunities to question and predict. Supports for creative thinking and meaningful problem solving (11)	○	○	○	○	○
Reflect Aistear, the early childhood curriculum framework for Ireland. (12)	○	○	○	○	○
Reflective of children's everyday lives and a focus on the everyday nature of STEM.	○	○	○	○	○
Holistic learning approaches and support for children's holistic development	○	○	○	○	○

Q19 If you want to add a caveat to answers, clarify a statement or suggest an edit to the answers above, you can do this in the space provided. Edits and clarifications are encouraged

Q20 The following items relate to the **role of the EC professional in supporting EC STEM**. Please rate the importance of the following items

	Not Important (1)	Neutral (2)	Somewhat Important (3)	Important (4)	Extremely Important (5)
Provide guided play experiences, and more structured materials or activities based on the child's STEM interests.	○	○	○	○	○
Act as a play partner, co-constructor of knowledge, co-learner, collaborator, and make discoveries with the child. Respect child's ideas and initiations	○	○	○	○	○
Be informed about EC STEM. Possess good knowledge of content and concepts for each discipline. Feel confident to introduce and support EC STEM.	○	○	○	○	○
Be aware of progression in STEM concepts and processes. Have the ability to use these in integrated, and in single-disciplinary ways.	○	○	○	○	○
Think about the world using a math- or science-lens. Model the attitudes and interests that position STEM as important, useful and connected to the world.	○	○	○	○	○
Support parents in relation to STEM. Educate parents about their crucial role in their child's STEM mind-set	○	○	○	○	○
Foster and build on children's curiosity. Pose questions. Encourage wonder. (7)	○	○	○	○	○

Notice and recognise STEM experiences happening in the setting and STEM ideas children are interested in. Provide new experiences and resources to extend children's STEM subject knowledge. (9)	○	○	○	○	○
Make STEM learning visible. Document children's STEM learning experiences (8)	○	○	○	○	○
Model and promote the language of STEM and STEM processes such as questioning, discussing, predicting and experimenting. (11)	○	○	○	○	○
Support children to use technology in the classroom in meaningful and appropriate ways (12)	○	○	○	○	○
Where necessary, explicitly teach STEM concepts such as counting or life cycles (13)	○	○	○	○	○

Q21 If you want to add a caveat to answers, clarify a statement or suggest an edit to the answers above, you can do this in the space provided. Edits and clarifications are encouraged

Section 3. STEM Knowledge, Pedagogy and Dispositions

Q23 The following statements relate to **essential knowledge early childhood professionals require** to successfully support early childhood STEM. Please rate the importance of each item

	Not Important (1)	Neutral (2)	Somewhat Important (3)	Important (4)	Extremely Important (5)
STEM content knowledge (for example, shape, space, and number in mathematics; living things, habitats or forces in science).	◯	◯	◯	◯	◯
What is meant by EC STEM; definitions and core ideas from each of the STEM disciplines that are appropriate for EC.)	◯	◯	◯	◯	◯
STEM fundamental concepts and processes (for example iterative design; problem finding and problem solving; theory generation)	◯	◯	◯	◯	◯
Ways of thinking that characterise STEM disciplines	◯	◯	◯	◯	◯
An understanding of key STEM developmental progressions. Knowledge of how to assess and plan for children's STEM progression based on interests and current knowledge.	◯	◯	◯	◯	◯
Appropriate STEM language e.g. mathematical language. Knowledge of the importance of questioning, discussing, talking with children about STEM subjects	◯	◯	◯	◯	◯

How to adapt or tailor STEM for the age group (babies, toddlers, young children).	○	○	○	○	○
How play, inquiry-based learning and the emergent curriculum framework support EC STEM. (8)	○	○	○	○	○
Understanding of technology and a high level of digital literacy. (9)	○	○	○	○	○
Knowledge of the arts. Knowledge and experience of doing creative things themselves (10)	○	○	○	○	○
How to identify if wellbeing, identity and belonging, communication is compromised due to a focus on STEM. (11)	○	○	○	○	○
Knowledge about how to research STEM topics WITH children, model learning as opposed to knowing everything, Foster a learning mind-set	○	○	○	○	○
Knowing where and how to access knowledge to support STEM investigation. Researching topic areas to increase knowledge and extend STEM learning experiences.	○	○	○	○	○

Q24 If you want to add a caveat to answers, clarify a statement or suggest an edit to the answers above, you can do this in the space provided. Edits and clarifications are encouraged

Q25 The following statements relate to essential **pedagogical approaches** required to successfully support early childhood STEM. Please rate the importance of each item

	Not Important (1)	Neutral (2)	Somewhat Important (3)	Important (4)	Extremely Important (5)
Strong, meaningful and trusting relationships with children. (1)	○	○	○	○	○
Slow nurturing pedagogy (2)	○	○	○	○	○
Open-ended play and exploration. Playful learning (3)	○	○	○	○	○
Project and enquiry based approaches; guiding interests over days or weeks. (4)	○	○	○	○	○
Extending children's interests. Recognising and building on funds of knowledge, starting from where the child is (5)	○	○	○	○	○
Talk and discussion including questioning, discussing, talking with children about STEM subjects, math talk. (6)	○	○	○	○	○
Opportunities for collaborative learning and group work (7)	○	○	○	○	○

Adequately assess and use appropriate technology. (8)	○	○	○	○	○
Engineering design process (9)	○	○	○	○	○
Balance between structured and open-ended approaches (10)	○	○	○	○	○
Sustained shared thinking. Supporting thinking skills. (11)	○	○	○	○	○
Pedagogical documentation. Be able to observe, write learning stories and use this information as foundation for next steps in planning and expanding interests. (12)	○	○	○	○	○
Early maths pedagogical approaches. For example, maths talk, counting principles, mathematising. (13)	○	○	○	○	○
Use of block play (15)	○	○	○	○	○
Modelling STEM skills, dispositions, attitudes and habits of mind; curiosity, persistence, theory generation, research, positive attitude toward STEM, positive STEM self-concept. (16)	○	○	○	○	○

Q26 If you want to add a caveat to answers, clarify a statement or suggest an edit to the answers above, you can do this in the space provided. Edits and clarifications are encouraged

Q27 The following statements relate to **essential attitudes and dispositions** early childhood professionals require to successfully support early childhood STEM. Please rate the importance of each item

	Not Important (1)	Neutral (2)	Somewhat Important (3)	Important (4)	Extremely Important (5)
A willingness to develop pedagogical content knowledge in STEM, view themselves as a learner (1)	○	○	○	○	○
Adaptable in the moment, flexible, open to change (2)	○	○	○	○	○
Able to say 'I don't know, let's find out'. (3)	○	○	○	○	○
Comfort with and willing to fail or make mistakes. Willingness to step outside of their own comfort zone. (4)	○	○	○	○	○
Comfortable with mess (5)	○	○	○	○	○
Curious. Possesses a general orientation that is curious about understanding the world	○	○	○	○	○
Enthusiastic, passionate (8)	○	○	○	○	○
Focused on fun (9)	○	○	○	○	○
Good communicator (10)	○	○	○	○	○
Happy to be with children. Find pleasure in their work. (11)	○	○	○	○	○

Have a belief in children's abilities. View of children as confident and capable learners. (12)	○	○	○	○	○
Imagination (14)	○	○	○	○	○
Interested. Wonders about things	○	○	○	○	○
Observant (17)	○	○	○	○	○
Patient (19)	○	○	○	○	○
Positive disposition toward STEM, positive views on the use of technology (21)	○	○	○	○	○
Positive disposition to STEM learning themselves (22)	○	○	○	○	○
Reflective (24)	○	○	○	○	○
Resilient (25)	○	○	○	○	○
Resourceful (26)	○	○	○	○	○
Respectful, responsive attitude to children's ideas and innovations (27)	○	○	○	○	○

Q28 If you want to add a caveat to answers, clarify a statement or suggest an edit to the answers above, you can do this in the space provided. Edits and clarifications are encouraged

Section 4. Sector-wide Support and Professional Development

Q30 The following statements relate to the most effective methods of **organising and facilitating early childhood STEM professional development**. Please rate the importance of each item

	Not important (1)	Neutral (2)	Somewhat Important (3)	Important (4)	Extremely Important (5)
Include content from all STEM disciplines in professional development i.e. Science, Technology, Engineering and Mathematics (1)	○	○	○	○	○
Include STEM concepts in professional development e.g. iterative design, generating theories, principles of counting, (2)	○	○	○	○	○
Ensure play is central. Provide examples of how disciplines can be integrated in a play environment. (3)	○	○	○	○	○
Support providers to notice and meaningfully engage with STEM already present in the daily routine, activities and curriculum. (4)	○	○	○	○	○
Learning by doing; hands-on experiences using STEM materials and processes. For example, using technology, digital artefact creation, project work. (5)	○	○	○	○	○
Time for reflection; consider what early childhood STEM looks like in their practice. (8)	○	○	○	○	○

Include opportunities for peer learning, sharing practice and analysing exemplars from practice. (9)	○	○	○	○	○
Provide multiple sessions, over months, to allow educators apply learning, to discuss practice on a number of occasions and tease out issues over time (10)	○	○	○	○	○
Tailor professional development to the context e.g. location, age group, setting type, person, characteristics of families/ community. (11)	○	○	○	○	○
Incentives for educators and supportive conditions for STEM professional development (replacement staff, paid training, time in lieu, professional development during work hours)	○	○	○	○	○
Flexible delivery. Blended professional development i.e. part online, part in person. (13)	○	○	○	○	○
A variety of professional development opportunities aligned to career stage and interest. Short introductory session for all. Intermediate professional development for managers and leaders. Advanced, subject-specific and accredited professional development for those with a strong interest. (15)	○	○	○	○	○

Q31 If you want to add a caveat to answers, clarify a statement or suggest an edit to the answers above, you can do this in the space provided. Edits and clarifications are encouraged

Q32 The following statements relate to the most effective methods of **supporting** early childhood professionals **after STEM professional development**. Please rate the importance of each item

	Not Important (1)	Neutral (2)	Somewhat Important (3)	Important (4)	Extremely Important (5)
Provision of STEM resources and materials for settings (1)	○	○	○	○	○
Informal, one-off, community-based learning opportunities using hands-on approaches e.g. in zoo, local library, museum, as part of maths week, community garden, SFI discover centres or training from tech companies (3)	○	○	○	○	○
Build security in new knowledge and understanding through ongoing supports after formal PD e.g. mentoring, facilitated community of practice, local networks for peer collaboration and observing the practice of others. (4)	○	○	○	○	○
Provision of further online information, resources, best practice examples and self-evaluation tools, vetted by experts and easily accessible to educators. Resources with various levels of detail i.e. introductory, intermediate and advanced. (5)	○	○	○	○	○
Support-based models where changes/improvements can be shared and discussed to develop and broaden a shared language around early STEM content and pedagogies. (6)	○	○	○	○	○

Q33 If you want to add a caveat to answers, clarify a statement or suggest an edit to the answers above, you can do this in the space provided. Edits and clarifications are encouraged

Q34 What **features of organisation at different levels** need to be in place to scale up early childhood STEM professional development

	Not Important (1)	Neutral (2)	Somewhat Important (3)	Important (4)	Extremely Important (5)
A clear vision for early childhood STEM across the sector. Commitment from multiple government Departments with responsibility for EC e.g. Department of Children; Department of Education	○	○	○	○	○
Government Departments to collaborate and take responsibility for the content of EC STEM professional development	○	○	○	○	○
Creation of an EC STEM Inter-Departmental group. Division of roles and responsibilities including rollout and evaluation of national EC STEM professional development.	○	○	○	○	○
Agreement by experts on EC STEM skills and knowledge requirements. Content of EC STEM professional development aligned with these requirements. (4)	○	○	○	○	○
Assessment of current capacity in relation to EC STEM, including; sector-wide survey; review of education inspection reports in relation to EC STEM; creation of an EC STEM expert panel. (5)	○	○	○	○	○

Established local and regional supports to facilitate EC STEM professional development events around the country i.e. Better Start; National Voluntary Childcare Organisations such as Barnardos or Early Childhood Ireland (6)	○	○	○	○	○
Inclusion of EC STEM in plans for local and regional support organisations. (7)	○	○	○	○	○
Inclusion of STEM in national EC guidelines i.e. Aistear the National Curriculum framework and Síolta the National Quality framework. (8)	○	○	○	○	○
STEM content to be included in all EC qualifications from level 5 to 8. Quality and Qualifications Ireland (QQI) and Further and Higher Education Institutions to be responsible for content of all EC initial qualifications (9)	○	○	○	○	○
Guaranteed funding, ring-fenced for specific EC STEM objectives; training, resources, ongoing supports (e.g. communities of practice, follow up training), assessment of current capacity. (10)	○	○	○	○	○
Provision of STEM professional development for teacher educators, mentors, inspectorate and others in support positions. (11)	○	○	○	○	○

Establish broader coalitions that enable multiple stakeholders to learn together and create a shared language and understanding i.e. educators, academics, mentors, inspectorate, curriculum bodies and EC policy makers (12)	○	○	○	○	○
Supportive STEM-informed Inspection from Tusla (The Child and Family Agency responsible for improving wellbeing and outcomes for children) and Department of Education Inspectorate (13)	○	○	○	○	○
A combination of top-down EC STEM policy and provision of EC STEM PD, coupled with bottom-up openings for sharing expertise	○	○	○	○	○

Q35 If you want to add a caveat to answers, clarify a statement or suggest an edit to the answers above, you can do this in the space provided. Edits and clarifications are encouraged

Q36 Have you any further comments or ideas that you would like to share?

Once again, I'm enormously grateful for your expertise and time. I'll be in touch with the third and final round in the coming weeks

Appendix 5: Sample Report to Experts, Round 2 to 3

Dear

Thank you for your continued interaction with this process, it is greatly appreciated. Responses to the last round of questionnaires have been collated and are presented below for your review. This information will help to inform your decisions in the third and final round. As such, it is important that you review this table **before** you complete the questionnaire, which you can access here.

In the following pages you will find comments and feedback from panel members *in italics*, as well as statistical data including

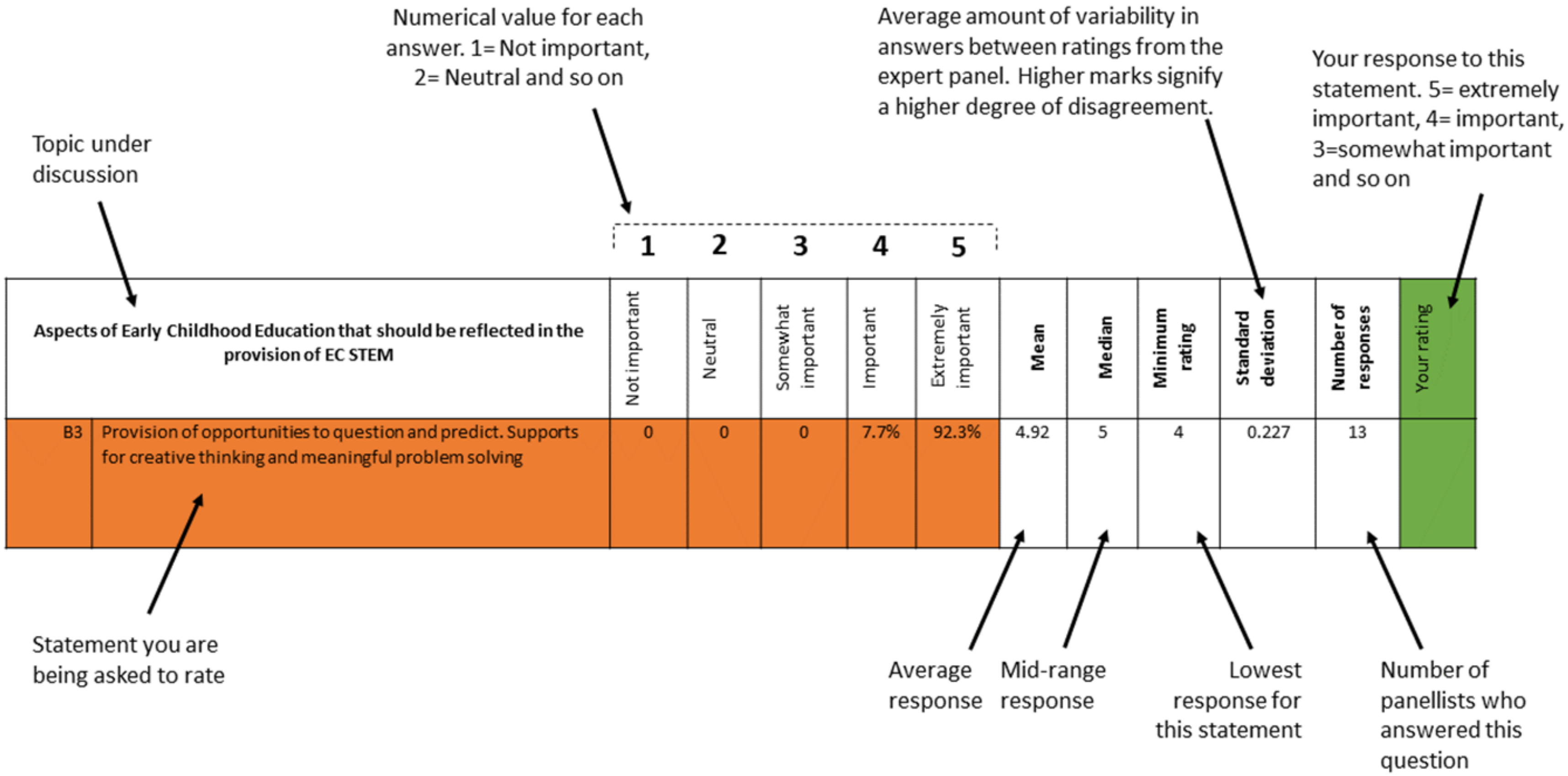
- the mean (average) rating for each statement
- the median (middle) rating for each statement
- the standard deviation (average amount of variability in answers) between ratings from across the expert panel. Higher marks signify a higher degree of variability.
- the minimum rating for each statement
- your rating for each statement in the last round. This is outlined in the final column of the table and is highlighted in green.

In addition, the table is colour coded, providing a visual representation of the level of consensus achieved in the last round.

- Orange signifies strong consensus
- Yellow signifies consensus
- Blue signifies consensus of disagreement i.e., the expert agrees this is not important
- No colour signifies that consensus was **not** reached in the last round.

Where statements have been adapted based on suggestions from panellists, this is noted.

Further details are provided overleaf but if you have any questions, please do not hesitate to contact me by email sandra.m.oneill@dcu.ie or call/ text 0879026747


Numerical value for each answer. 1= Not important, 2= Neutral and so on
Average amount of variability in answers between ratings from the expert panel. Higher marks signify a higher degree of disagreement.
Your response to this statement. 5= extremely important, 4= important, 3=somewhat important and so on
Topic under discussion
1 2 3 4 5
Aspects of Early Childhood Education that should be reflected in the provision of EC STEM
Not important
Neutral
Somewhat important
Important
Extremely important
Mean
Median
Minimum rating
Standard deviation
Number of responses
Your rating
B3
Provision of opportunities to question and predict. Supports for creative thinking and meaningful problem solving
0
0
0
7.7%
92.3%
4.92
5
4
0.227
13
Statement you are being asked to rate
Average response
Mid-range response
Lowest response for this statement
Number of panellists who answered this question

Section A – Defining STEM

	Essential elements of an Early Childhood STEM definition.	Not important	Neutral	Somewhat important	Important	Extremely important	**Mean**	**Median**	**Minimum rating**	**Standard deviation**	**Number of responses**	**Your rating**
A1	Science, Technology, Engineering, Math	0	0	0	7.7%	92.3%	4.9	5	4	0.277	13	
A8	Play	0	0	0	15.4%	84.6%	4.8	5	4	0.375	13	
A4	Critical thinking	0	0	7.7%	7.7%	84.6%	4.8	5	3	0.599	13	
A2	Curiosity	0	0	7.7%	7.7%	84.6%	4.7	5	3	0.599	13	
A3	Creativity, imagination	0	0	0	23.1%	76.9%	4.7	5	4	0.438	13	
A7	Innovation	0	0	15.4%	46.1%	38.5%	4.2	4	3	0.725	13	
A5	Language of STEM	0	0	23.1%	30.8%	46.1%	4.2	4	3	0.832	13	
A6	the Arts	7.7%	15.4%	7.7%	15.4%	53.8%	3.9	5	1	1.441	13	

Essential elements of an Early Childhood STEM definition - Comments from the Expert Panel

While the language of STEM is important, I do not see it as essential to a definition.

The Arts has been listed as important rather than very important. There has been some debate about incorporating the Arts into STEM as it may lessen the importance of the Arts as a distinct discipline if it is incorporated into STEM.

I think the Arts and STEM are both of equal value and importance, but one should not be subservient to the other even though they both work towards overall learning goals for children and students. Both areas of learning need and deserve their own space. There can be a danger of subsuming the arts into STEM. I think that it should be STEM and the Arts rather than STE(A)M.

	Integration of subjects/ disciplines in Early Childhood STEM.	Not important	Neutral	Somewhat important	Important	Extremely important	**Mean**	**Median**	**Minimum rating**	**Standard deviation**	**Number of responses**	**Your rating**
A10	STEM disciplines naturally coexist and overlap in EC settings. One or more STEM disciplines can arise during play and/or routine activities leading to integration.	0	0	0	7.7%	92.3%	4.9	5	4	0.277	13	
A14	The use of the project approach or long-term investigations supports integration of STEM subjects over time.	0	0	0	15.4%	84.6%	4.8	5	4	0.375	13	
A11	Young children do not learn in discrete categories or subject areas. Some subject content can be supported independently (e.g., counting or measure in mathematics)	0	0	0	23.1%	76.9%	4.78	5	4	0.438	13	
A12	Exposure to the ways of thinking that characterise each of the subjects is equally important e.g. using a maths lens, engineering habits of mind	0	0	15.4%	38.5%	46.1%	4.3	4	3	0.751	13	
A16	Integrated learning leads to richer experiences for children	0	7.7%	0	15.4%	76.9%	4.6	5	2	0.86	13	
A9	EC STEM is any experience, activity, routine or discussion involving a STEM discipline (**either** science, technology, engineering, math or a combination of these disciplines)	7.7%	0	0	15.4%	76.9%	4.5	5	1	1.126	13	
A13	STEM subjects taught alone could lead to more directive teaching style. Planned STEM activities are not required, and prescriptive approaches should be avoided	15.4%	23.1%	15.4%	15.4%	30.8%	3.2	3	1	1.54	13	
A15	To support children's STEM learning, an equitable inclusion of all four disciplines should be provided in the course of the term/ year, and within the curriculum.	23.1%	15.4%	23.1%	23.1%	15.4%	2.9	3	1	1.44	13	

Integration of subjects/ disciplines in early childhood STEM - Comments from the Expert Panel

I don't see disciplinary teaching as necessarily involving more directive approaches than integrated teaching - subjects can be handled playfully and responsively, and my sense is that this is sometimes quite useful to do.

I agree with the first part the statement 'STEM subjects taught alone could lead to more directive teaching style' However, I may be interpreting this section of the statement differently than intended 'planned STEM activities are not required' ... I think we do need planned STEM activities as part of intentional pedagogy in ECEC. For example, introducing digital technologies such as Beebots or robotics kits to support computational thinking need to be intentionally planned by the educator. I don't view planned STEM activities as being the same as STEM subject activities.

Some planned STEM activities can be useful but should not dominate. It depends on the group of children and their interests.

I don't think that there needs to be equity in inclusion of all 4 disciplines as it will depend on the interests of the children individually and in groups and how projects evolve. Awareness of the importance of all and how they can be incorporated is important for educators, with flexibility around how much of each one is covered over a term, but with an aim of covering elements of each discipline over a 2-year period. There should be room for both planned and emergent approaches (emergent interests can lead to relevant plans by educators), as well as individual subjects and integration of subjects, depending on children's interests.

My concern with the second last statement, about equitable inclusion is that children's interests, and inquiry need to be considered too. Educators need to be aware of all aspects, but things that happen in the environment, the funds of knowledge or the children and/ or educators are factors too.

Attempting to achieve an equitable inclusion of all four disciplines should be not be advocated, this has the potential for to lead to prescriptive approaches which may take from following the children's natural curiosity and creativity.

It would be impossible to include the equitable inclusion of all four disciplines in the course of the term/year. It all depends on what a particular group of children are interested in.

Aspects of Early Childhood Education that should be reflected in the provision of EC STEM		Not important	Neutral	Somewhat important	Important	Extremely important	**Mean**	**Median**	**Minimum rating**	**Standard deviation**	**Number of responses**	**Your rating**
B1	Play, active learning and hands-on experiences.	0	0	0	0	100%	5	5	5	0	13	
B7	Children's agency, child-led approaches, respecting children's freedom to make choices	0	0	0	0	100%	5	5	5	0	13	
B3	Provision of opportunities to question and predict. Supports for creative thinking and meaningful problem solving	0	0	0	7.7%	92.3%	4.92	5	4	0.227	13	
B9	Emergent approaches. Building on children's interests. Using children's interests as starting points for investigations	0	0	0	7.7%	92.3%	4.92	5	4	0.227	13	
B5	Reflective of children's everyday lives and a focus on the everyday nature of STEM.	0	0	0	15.4%	84.6%	4.85	5	4	0.375	13	
B6	Holistic learning approaches and support for children's holistic development	0	0	0	15.4%	84.6%	4.85	5	4	0.375	13	
B8	The use of everyday, simple and open-ended materials. The use of the outdoors and nature	0	0	0	15.4%	84.6%	4.85	5	4	0.375	13	
B10	Inquiry-based approaches including the use of projects and long-term investigations	0	0	0	15.4%	84.6%	4.85	5	4	0.375	13	
B12	Co-construction of knowledge between adult and child	0	0	0	15.4%	84.6%	4.85	5	4	0.375	13	
B2	Slow pedagogy	0	0	0	23.1%	76.9%	4.77	5	4	0.438	13	

B11	The provision of play invitations and prompts to provoke inquiry, engage curiosity and creativity	0	0	0	23.1%	76.9%	4.77	5	4	0.438	13	
B4	Reflect Aistear, the early childhood curriculum framework for Ireland.	0	15.4%	7.7%	7.7%	69.3%	4.30	5	2	1.18	13	

Aspects of Early Childhood Education that should be reflected in the provision of EC STEM - Comments from the Expert Panel

The use of outdoors and nature is not emphasised enough in relation to STEM.

All aspects included are really important. Starting where children are at/ funds of knowledge, slow pedagogy, play, co-construction are vital especially. Outdoor play is also of prime importance.

Suggestions for inclusion in this section - Using technology to support learning, particularly research and observations by educators and children. The use of books and other literacy materials to support STEM learning. Process-led, creative representation of STEM learning and knowledge by children. Sharing children's STEM learning and interests between home and the setting Connecting with informal STEM education settings and experts to enrich learning experiences.

	The role of the EC professional in relation to STEM	Not important	Neutral	Somewhat important	Important	Extremely important	**Mean**	**Median**	**Minimum rating**	**Standard deviation**	**Number of responses**	**Your rating**
B22	Foster and build on children's curiosity. Pose questions. Encourage wonder. Ask 'I wonder' questions	0	0	0	0	100%	5	5	5	0	13	
B17	Act as a play partner, co-constructor of knowledge, co-learner, collaborator, and make discoveries with the child. Respect child's ideas and initiations	0	0	0	7.7%	92.3%	4.92	5	4	0.227	13	
B24	Notice and recognise STEM experiences happening in the setting, the STEM ideas children are interested in, their existing funds of knowledge and plan to expand these. Provide new experiences and resources to extend on children's STEM and subject knowledge.	0	0	0	7.7%	92.3%	4.92	5	4	0.227	13	
B14	Model and promote the language of STEM and STEM processes such as questioning, discussing, predicting and experimenting.	0	0	0	23.1%	76.9%	4.77	5	4	0.438	13	
B23	Make STEM learning visible. Document children's STEM learning experiences	0	0	7.7%	15.4%	76.9%	4.69	5	3	0.630	13	
B20	Think about the world using a math- or science-lens. Provide children with strong foundations by modelling the attitudes and interests that position STEM as important, useful and connected to the world.	0	0	15.4%	23.1%	61.5%	4.46	5	3	0.776	13	
B18	Be informed about EC STEM. Possess good knowledge content areas and concepts for each discipline. Confident to introduce support EC STEM.	0	0	7.7%	46.1%	46.1%	4.38	4	3	0.650	13	

B13	Provide guided play experiences, and more structured materials or activities based on the child's STEM interests.	0	0	23.1%	38.5%	38.5%	4.15	4	3	0.800	13	
B21	Support parents in relation to STEM. Educate parents about their crucial role in their child's STEM mind-set	0	0	7.7%	69.2%	23.1%	4.15	4	3	0.554	13	
B15	Support children to use technology in the classroom in meaningful and appropriate ways	0	7.7%	0	46.1%	46.1%	4.31	4	2	0.854	13	
B19	Be aware of progression in STEM concepts and processes. Have the ability to use these in integrated, and in single-disciplinary ways.	0	7.7%	15.4%	38.5%	38.5%	4.08	4	2	0.954	13	
B16	Where necessary, explicitly teach STEM concepts such as counting or life cycles	23.1%	7.7%	0	46.1%	23.1%	3.38	4	1	1.556	13	

The role of the EC professional in relation to STEM - Comments from the Expert Panel

I think I prefer combinations of pedagogic approaches rather than more singular approaches - so guided play may happen on some occasions but should not be the only approach used.

Guided play, structured materials and explicit teaching should only be used if relevant to the particular context and group of children. In some instances, these more 'formal' activities could dominate and lead to the schoolification of STEM in early childhood.

Technology - I think this depends on what the definition of technology is and the age range it is aimed at. Materials to support children to extend their learning and promote their questioning and curiosity such as microscopes or cameras are, in my opinion, suitable and valuable additions to the classroom. Cash registers that allow children to pay by 'credit card' are also, in my opinion, suitable and age appropriate. I am less convinced of the use of tablets or phones to support research. In the first instance, children should be guided towards books before being introduced to digital research.

I think the use of technology is really important in terms of how to approach embedding digital technologies in ECEC.

The last point, explicitly teach STEM concepts: I have indicated that this is not important here but if a child or group of children express interest in this then of course it is important. It is not something that should 'be on the curriculum' each year however regardless of children's interests. Concepts such as life cycles *and counting can be introduced to children very organically though play with nature and to me, this is much more preferable than being 'traditionally' taught this through flashcards and wall displays.*

Where explicit teaching takes place, it should obviously be done in a way that is appropriate for the children's stage of development and that aligns to the child's interests. This should be possible when well-trained educators are also really familiar with individual children, their stages of development and their interests.

I do think there is a place for intentional and explicit teaching of concepts as long as underpinned by a playful approach to learning.

While possessing a good knowledge of STEM content and concepts is important. I have considered this in relation to the context of the sector at present. There are increasing demands on settings who are understaffed. Placing an additional demand to gain the knowledge could be off-putting. Rather, it could be more beneficial to highlight how professionals are already using STEM concepts and processes in their support of children's play.

	Essential knowledge early childhood professionals require to successfully support early childhood STEM.	Not important	Neutral	Somewhat important	Important	Extremely important	**Mean**	**Median**	**Minimum rating**	**Standard deviation**	**Number of responses**	**Your rating**
C7	How to adapt or tailor STEM for the age group (babies, toddlers, young children).	0	0	0	7.7%	92.3%	4.9	5	4	0.277	13	
C8	How play, inquiry-based learning and the emergent curriculum framework support EC STEM.	0	0	0	7.7%	92.3%	4.9	5	4	0.277	13	
C12	Knowledge of co-construction, how to research STEM topics with children, model learning as opposed to knowing everything; Foster a learning mind-set.	0	0	7.7%	7.7%	84.6%	4.77	5	3	0.599	13	
C6	Appropriate STEM language including math language. Knowledge of the importance of questioning, discussing, talking with children about STEM subjects	0	0	0	38.5%	61.5%	4.62	5	4	0.506	13	
C4	Ways of thinking that characterise STEM disciplines	0	0	7.7%	46.2%	46.2%	4.38	4	3	0.650	13	
C13	Knowing where and how to access knowledge to support STEM investigation. Researching topic areas to increase knowledge and extend STEM learning experiences.	0	0	7.7%	53.8%	38.5%	4.31	4	3	0.630	13	
C1	STEM content knowledge (for example, shape, space, and number in mathematics; living things, habitats or forces in science).	0	0	7.7%	69.2%	23.1%	4.15	4	3	0.554	13	
C2	What is meant by EC STEM; definitions and core ideas from each STEM discipline that are appropriate for EC.	0	0	15.4%	53.8%	30.8%	4.15	4	3	0.688	13	
C10	Knowledge of the arts. Knowledge and experience of doing creative things themselves	0	0	30.8%	30.8%	38.5%	4.08	4	3	0.862	13	

Essential knowledge early childhood professionals require to successfully support early childhood STEM.		Not important	Neutral	Somewhat important	Important	Extremely important	**Mean**	**Median**	**Minimum rating**	**Standard deviation**	**Number of responses**	**Your rating**
C5	An understanding of key STEM developmental progressions. Knowledge of how to assess and plan for children's STEM progression based on interests and current knowledge.	7.7%	0	7.7%	23.1%	61.5%	4.31	5	1	1.182	13	
C11	How to identify if wellbeing, identity and belonging, communication is compromised due to a focus on STEM. *In the next round, this statement will be changed to: Knowledge and awareness to foster approaches to STEM which ensure children's wellbeing, identity and belonging and communication are encouraged and supported within STEM learning experiences.*	7.7%	15.4%	7.7%	15.4%	53.8%	3.85	5	1	1.441	13	
C3	STEM fundamental concepts and processes (for example iterative design; problem finding and problem solving; theory generation)	7.7%	0	15.4%	69.2%	7.7%	3.69	4	3	0.947	13	
C9	Understanding of technology and a high level of digital literacy. *In the next round, this statement will be changed to: Knowledge and experience of using digital technologies creatively*	7.7%	15.4%	15.4%	46.2%	15.4%	3.46	4	1	1.198	13	

Essential knowledge early childhood professionals require to successfully support early childhood STEM - Comments from the Expert Panel

A high level of digital literacy would be preferable, but not realistic or essential at the moment as the majority of society does not have high-level of digital literacy. An openness to engage with digital technology and learn more would be an essential requirement for me.

I was put off by the well-being statement, in particular, the use of language 'compromised'. I do not see how focusing on STEM might compromise well-being, identity and belonging if the professional follows a child-centred focus. I would suggest not being child-centred would be the biggest reason for compromised wellbeing and I&B.

Some of the language used above is not in line with my own personal values. For example. essential knowledge that early childhood professionals 'require'. This suggests a level of accountability in relation to what professionals do and don't know.

STEM 'developmental progressions'. This could lead to a focus on what children cannot do rather than what they can if we are assessing them against expected progressions.

This is a tricky one. Subject matter knowledge is important, but not covered in many (any?) courses/ training/ CPD. Its important educators don't feel overwhelmed by the idea that they have to know a lot or gain a lot of knowledge to enable them to support STEM in their settings. Knowledge about how to research with children and understanding how play can enable children to be curious explorers can go a long way.

Essential pedagogical approaches professionals require to successfully support EC STEM.		Not important	Neutral	Somewhat important	Important	Extremely important	**Mean**	**Median**	**Minimum rating**	**Standard deviation**	**Number of responses**	**Your rating**
C19	Provide opportunities for collaborative learning. Planning for group work.	0	0	0	7.7%	92.3%	4.9	5	4	0.277	13	
C13	Strong, meaningful and trusting relationships with children.	0	0	7.7%	0	92.3%	4.85	5	3	0.554	13	
C18	Talk and discussion including questioning, discussing, talking with children about STEM subjects, math talk.	0	0	0	15.4%	84.6%	4.85	5	4	0.375	13	
C26	Use of block play	0	0	0	15.4%	84.6%	4.85	5	4	0.375	13	
C27	Modelling STEM skills, dispositions, attitudes, habits of mind; curiosity, persistence, theory generation, positive STEM self-concept.	0	0	0	15.4%	84.6%	4.85	5	4	0.375	13	
C24	Pedagogical documentation. Be able to observe, write learning stories for next steps in planning and expanding interests.	0	0	0	30.8%	69.2%	4.69	5	4	0.480	13	
C14	Slow nurturing pedagogy	0	0	7.7%	15.4%	76.9%	4.69	5	3	0.630	13	
C16	Project/enquiry-based approaches; guiding interests over days or weeks.	0	0	7.7%	15.4%	76.9%	4.69	5	3	0.630	13	
C23	Sustained shared thinking. Supporting thinking skills.	0	0	15.4%	7.7%	76.9%	4.62	5	3	0.767	13	
C20	Adequately assess and use appropriate technology.	0	0	15.4%	30.8%	53.8%	4.38	5	3	0.767	13	

C25	Early maths pedagogical approaches. For example, maths talk, counting principles, mathematising.	0	0	15.4%	30.8%	53.8%	4.38	5	3	0.767	13	
C22	Balance between structured and open-ended approaches	0	0	23.1%	23.1%	53.8%	4.31	5	3	0.854	13	
C21	Engineering design process	0	0	30.8%	30.8%	38.5%	4.07	4	3	0.862	13	

Essential pedagogical approaches professionals require to successfully support EC STEM - Comments from the Expert Panel

Being present with children in play and being willing to play alongside them if requested by the children, in order to be aware of children's interests and opportunities for STEM learning that arise. Nurturing curiosity, wonder and learning around STEM in your own life, so that these habits and dispositions become habitual and hopefully infectious!

Essential dispositions/ attitudes EC professionals require to successfully support EC STEM.		Not important	Neutral	Somewhat important	Important	Extremely important	**Mean**	**Median**	**Minimum rating**	**Standard deviation**	**Responses**	**Your rating**
C38	Happy to be with children. Find pleasure in their work.	0	0	0	0	100%	5	5	5	0	13	
C39	Have a belief in children's abilities. View of children as confident and capable learners.	0	0	0	0	100%	5	5	5	0	13	
C42	Observant	0	0	0	0	100%	5	5	5	0	13	
C49	Respectful, responsive attitude to children's ideas and innovations	0	0	0	0	100%	5	5	5	0	13	
C31	Able to say 'I don't know, let's find out'.	0	0	0	7.7%	92.3%	4.9	5	4	0.277	13	
C37	Good communicator	0	0	0	7.7%	92.3%	4.9	5	4	0.277	13	
C43	Patient	0	0	0	7.7%	92.3%	4.9	5	4	0.277	13	
C46	Reflective	0	0	0	7.7%	92.3%	4.9	5	4	0.277	13	
C28	A willingness to develop pedagogical content knowledge in STEM, view themselves as a learner	0	0	0	15.4%	84.6%	4.85	5	4	0.375	13	
C30	Adaptable in the moment, flexible, open to change	0	0	0	15.4%	84.6%	4.85	5	4	0.375	13	
C32	Comfort with and willing to fail or make mistakes. Willingness to step outside of their own comfort zone.	0	0	0	15.4%	84.6%	4.85	5	4	0.375	13	
C34	Possesses a general orientation that is curious about understanding the world	0	0	0	15.4%	84.6%	4.85	5	4	0.375	13	
C40	Imagination	0	0	0	15.4%	84.6%	4.85	5	4	0.375	13	

Essential dispositions/ attitudes EC professionals require to successfully support EC STEM.		Not important	Neutral	Somewhat important	Important	Extremely important	**Mean**	**Median**	**Minimum rating**	**Standard deviation**	**Number of responses**	**Your rating**
C41	Interested. Wonders about things.	0	0	0	15.4%	84.6%	4.85	5	4	0.375	13	
C33	Comfortable with mess	0	0	0	23.1%	76.9%	4	5	4	0.438	13	
C35	Enthusiastic. Passionate	0	0	0	23.1%	76.9%	4	5	4	0.438	13	
C47	Resilient	0	0	0	23.1%	76.9%	4	5	4	0.438	13	
C48	Resourceful	0	0	0	23.1%	76.9%	4	5	4	0.438	13	
C36	Focused on fun *In the next round, this statement will be changed to:A willingness to be playful*	0	0	15.4%	15.4%	69.2%	4.53	5	3	0.776	13	
C44	Positive disposition toward STEM, positive views on the use of technology	0	0	0	38.5%	61.5%	4.62	5	4	0.497	13	
C45	Positive disposition to STEM learning themselves	0	0	0	46.2%	53.8%	4.54	5	4	0.518	13	

Essential dispositions/ attitudes EC professionals require to successfully support EC STEM - Comments from the Expert Panel

With the exception of the specific mention of STEM, many of the pedagogical approaches listed are what is promoted by Aistear in relation to working with children. These apply regardless of STEM or other learning areas.

I suggest that the attitudes and dispositions listed are essential to be a high-quality educator and not merely focused on STEM.

Effective methods of organising and facilitating EC STEM professional development.		Not important	Neutral	Somewhat important	Important	Extremely important	**Mean**	**Median**	**Minimum rating**	**Standard deviation**	**Number of responses**	**Your rating**
D3	Ensure play is at the forefront of how STEM is considered in practice. Provide examples of how subjects can be integrated in a play environment	0	0	0	0	100%	5	5	5	0	13	
D4	Support providers to notice and meaningfully engage with STEM already present in the daily routine, activities, and curriculum.	0	0	0	7.7%	92.3%	4.9	5	4	0.277	13	
D8	Provide multiple sessions, over months, to allow educators apply learning, to discuss practice on a number of occasions and tease out issues over time	0	0	0	15.4%	84.6%	4.85	5	4	0.375	13	
D7	Include opportunities for peer learning, sharing practice and analysing exemplars from practice.	0	0	0	23.1%	76.9%	4.78	5	4	0.438	13	
D10	Incentives for educators and supportive conditions for STEM professional development (replacement staff, paid training, time in lieu, professional development during work hours)	0	0	0	23.1%	76.9%	4.78	5	4	0.438	13	
D5	Learning by doing with hands-on experiences using STEM materials and processes. For example, using technology, digital artefact creation, project work	0	0	0	38.5%	61.5%	4.62	5	4	0.506	13	
D11	Flexible delivery. Blended professional development i.e. part online, part in person.	0	0	7.7%	30.8%	61.5%	4.54	5	3	0.660	13	

Effective methods of organising and facilitating EC STEM professional development.		Not important	Neutral	Somewhat important	Important	Extremely	Mean	Median	Minimum rating	Standard deviation	Number of	
D1	Include content from all STEM disciplines in professional development i.e. Science, Technology, Engineering and Mathematics	0	0	15.4%	46.1%	38.5%	4.23	4	3	0.725	13	
D6	Time for reflection. Consider what early childhood STEM looks like in their practice.	0	0	0	84.6%	15.4%	4.15	4	4	0.375	13	
D2	Include STEM concepts in professional development e.g., iterative design, generating theories, principles of counting, problem finding and problem solving, mathematising	0	0	15.4%	53.8%	38.5%	4.15	4	3	0.688	13	
D12	Provision of a variety of professional development opportunities aligned to career stage and interest. Short introductory session for all. Intermediate professional development for managers and leaders. Advanced, subject-specific and accredited professional development for those with a strong interest.	0	0	7.7%	7.7%	84.6%	4	5	3	0.599	13	
D9	Tailor professional development to the context e.g. location, age group, setting type, person, characteristics of families/ community.	7.7%	0	0	30.8%	61.5%	4.38	5	1	1.120	13	

Effective methods of organising and facilitating EC STEM professional development - Comments from the Expert Panel

The statement on 'tailor professional development to the context', it would be good to have PD development that takes place in the early childhood setting, for example through mentoring visits and opportunities for educators to engage in practice-based inquiry; how they can integrate or embed STEM practices into their curriculum.

Including content from STEM disciplines could put people off particularly if they had negative experiences of these areas in the past. The way that the content would be introduced is important. For example, a top-down teacherly approach should be avoided. Links to early years practice at all times would be important, demonstrating how this content knowledge can be used in 'real life' everyday practice.

Opportunities for educators to develop their own STEM wonder through outings to STEM settings such as zoos/parks/etc where experts can support the educators learning, in groups with fellow educators.

Effective methods of supporting EC professionals after STEM professional development.		Not important %	Neutral %	Somewhat important %	Important %	Extremely important %	**Mean**	**Median**	**Minimum rating**	**Standard deviation**	**Number of responses**	**Your rating**
D16	Build security in new knowledge and understanding through ongoing supports after formal PD e.g. mentoring, facilitated community of practice, local networks for peer collaboration and observing the practice of others.	0	0	0	30.8	69.2	4.69	5	4	0.480	13	
D17	Provision of further online information, resources, best practice examples and self-evaluation tools, vetted by experts and easily accessible to educators. Resources with various levels of detail i.e. introductory, intermediate and advanced.	0	0	0	38.5	61.5	4.62	5	4	0.506	13	
D18	Support-based models where changes/ improvements can be shared and discussed to develop and broaden a shared language around early STEM content and pedagogies.	0	0	0	38.5	61.5	4.62	5	4	0.506	13	
D13	Provision of STEM resources and materials for settings to support application of learning from professional development opportunities	0	0	7.7	69.2	23.1	4.15	4	3	0.554	13	
D14	Informal, one-off, community-based learning opportunities using hands-on approaches e.g. in zoo, local library, museum, as part of maths week, community garden, SFI discover centres or training from tech companies	0	0	46.1	23.1	30.8	3.85	4	3	0.898	13	

Effective methods of supporting EC professionals after STEM professional development - Comments from the Expert Panel

While STEM materials can be useful and can be an 'incentive' to participate in professional development. STEM processes are not reliant in specific materials. Many STEM concepts and processes can become evident from exploration of and interactions in the natural environment.

I would rather see prioritisation of funding for training of educators than materials, though both would be best. Consideration of a well-funded EC STEM conference for educators, with expert speakers from all areas within the sector-educators, researchers, Government Departments, experts from different STEM areas, etc with awards for excellence in practice and research.

One off events are of course important, but ongoing research circles, community of practice give more consistent ongoing support and inspiration

Features of organisation that need to be in place to scale up EC STEM professional development.		Not important	Neutral	Somewhat important	Important	Extremely important	**Mean**	**Median**	**Minimum rating**	**Standard deviation**	**Number of responses**	**Your rating**
D29	Provision of STEM professional development for teacher educators, mentors, inspectorate, and others in support positions.	0	0	0	18.2%	81.8%	4.82	5	4	0.404	11	
D27	STEM content to be included in all initial professional education for early childhood from level 5 to 8. Quality and Qualifications Ireland (QQI) and Further and Higher Education Institutions to be responsible for content of all early years education initial qualifications	0	0	0	27.3%	72.7%	4.72	5	4	0.467	11	
D28	Guaranteed funding, ring-fenced for specific EC STEM objectives; training, resources, ongoing supports (e.g., communities of practice, follow up training), assessment of current capacity.	0	0	0	27.3%	72.7%	4.72	5	4	0.467	11	
D26	Inclusion of STEM in national early childhood guidelines i.e., Aistear and Síolta.	0	0	0	33.3%	66.7%	4.66	5	4	0.492	12	
D19	A clear vision for early childhood STEM across the sector. Commitment from multiple government Departments with responsibility for EC e.g., Department of Children; Department of Education	0	0	0	41.7%	58.3%	4.58	5	4	0.515	12	
D30	Establish broader coalitions that enable multiple stakeholders to learn together and create a shared language and understanding i.e., educators, academics, mentors, inspectorate, curriculum bodies and EC policy makers	0	0	0	50 %	50%	4.5	4.5	4	0.522	12	
D25	Inclusion of early childhood STEM in plans for local and regional support organisations.	0	0	7.7%	38.5%	53.8%	4.46	5	3	0.660	13	
D20	Government Departments to collaborate and take responsibility for the content of early childhood STEM professional development	0	0	16.7%	25%	58.3%	4.42	5	3	0.792	12	

D24	Established local and regional supports will facilitate early childhood STEM professional development events around the country i.e., Better Start; National Voluntary Childcare Organisations such as Barnardos or Early Childhood Ireland	0	0	18.2%	27.3%	54.5%	4.36	5	3	0.809	11	

Features of organisation that need to be in place to scale up EC STEM professional development.	Not important	Neutral	Somewhat important	Important	Extremely important	**Mean**	**Median**	**Minimum rating**	**Standard deviation**	**Number of responses**	**Your rating**
A combination of top-down EC STEM policy and provision of EC STEM PD, coupled with bottom-up openings for sharing expertise.	0	0	18.2%	27.3%	54.5%	4.36	5	3	0.809	11	
Creation of an early Childhood STEM Inter-Departmental group. Division of roles and responsibilities including rollout and evaluation of national early childhood STEM professional development	0	0	16.7%	33.3%	50 %	4.33	4.5	3	0.778	12	
Agreement by experts on early childhood STEM skills and knowledge requirements. Content of early childhood STEM professional development to be aligned with these requirements.	0	0	16.7%	33.3%	50 %	4.33	4.5	3	0.778	12	
Assessment of current capacity in relation to early childhood STEM, including but not limited to; sector-wide survey; review of education inspection reports in relation to early childhood STEM; creation of an early childhood STEM expert panel.	0	0	18.2%	36.4%	45.5%	4.27	4	3	0.786	11	
Supportive STEM-informed Inspection from Tusla (The Child and Family Agency responsible for improving wellbeing and outcomes for children) and Department of Education Inspectorate	0	0	18.2%	36.4%	45.5%	4.27	4	3	0.786	11	

Features of organisation that need to be in place to scale up EC STEM professional development - Comments from the Expert Panel

I would be nervous as to what the STEM PD would look like if government departments take responsibility for the content. I think they can be responsible for the overarching ideas and aims, rather than the content. I think an EC STEM expert panel would be valuable, however hesitant/sceptical about sector-wide surveys that will highlight the lack of capacity or gaps etc and nothing will be done about it.

Aligning professional development to a set of required skills, government departments taking responsibility for STEM. evaluation etc. reflects a neoliberalist perspective. The inclusion of STEM should not be a requirement from outside departments/agencies. It is my view that STEM should be included because professionals 'want to' not because they 'have to'. I do however feel that local and regional communities of practice can support this process and funding for this would be beneficial.

Need to place STEM within holistic learning and development, only one part. Am fearful of a push down of subject and look at the damage higher level maths in the leaving cert with its bonus points caused. We need to be really careful here. Wellbeing, identity and belonging, communicating and exploring and thinking are equally important as set out in Aistear. Also where is sustainability in STEM - not jumping out here, feel there is a push down with policies and agendas that are not always in the best interests of children, time to be to experience wonder and awe - the STEM language can come later - remember david elkind and the hurried child

You can view the full version here - having trouble adding it to the google doc so I'll do this once I transfer everything over to a word document

Appendix 6: Round 3 Questionnaire

DELPHI ROUND 3

Q1 **Thank you** for your timely and insightful completion of the last round of this Delphi study. I greatly appreciate your invaluable expertise, given the many competing demands on your time and I apologise again for my own tardiness

In round 3 the same statements from round 2 are put to you again. This time you have additional information including opinions and ratings from the other members of the expert panel.

If you want to comment, provide an explanation for your position, explain why you disagree with the majority or question why a statement is included, you can do this in the space provided after each section. You **are encouraged** to add your thoughts and ideas. These will be reported on in the final study report.

In order to maintain my scheduled timeline I would be most grateful if you could complete the questionnaire by **20th October**
I am enormously grateful for your expertise and time.
Sandra

Informed consent

Q2 I have read and understood the project information sheet dated April 2023 or the project has been fully explained to me. (If you will answer No to this question please do not proceed with this consent form until you are fully aware of what your participation in the project will mean.)

○ Yes (1)

○ No (2)

Q3 I have been given the opportunity to ask questions about the project.

○ Yes (1)

○ No (2)

Q4 I agree to take part in the project. I understand that taking part in the project will include the completion of three questionnaires over the course of 3-4 months

◯ Yes (1)

◯ No (2)

Q5 I understand that by choosing to participate as a volunteer in this research, this does not create a legally binding agreement nor is it intended to create an employment relationship with the University of Sheffield.

◯ Yes (1)

◯ No (2)

Q6 I understand that my taking part is voluntary and that I can withdraw from the study at any time. I understand that once the first questionnaire has been submitted this data cannot be withdrawn from the project but that I can withdraw from any on-going or future data collection; I do not have to give any reasons for why I no longer want to take part and there will be no adverse consequences if I choose to withdraw.

◯ Yes (1)

◯ No (2)

Q7 I understand my personal details such as name, phone number and email address etc. will not be revealed to people outside the project.

◯ Yes (1)

◯ No (2)

Q8 I understand and agree that my words may be quoted in publications, reports, web pages, and other research outputs. I understand that I will not be named in these outputs unless I specifically request this.

○ Yes (1)

○ No (2)

Q9 I understand and agree that ED Supervisors from the University of Sheffield will have access to this data in an pseudonymised format only if they agree to preserve the confidentiality of the information as requested in this form.

○ Yes (1)

○ No (2)

Q10 I understand and agree that other authorised researchers may use my data in publications, reports, web pages, and other research outputs, only if they agree to preserve the confidentiality of the information as requested in this form. I understand that I will be asked to provide explicit consent for use of data in other publications

○ Yes (1)

○ No (2)

Q11 I agree to assign the copyright I hold in any materials generated as part of this project to The University of Sheffield.

○ Yes (1)

○ No (2)

Section 1. Defining Early Childhood STEM

Q13 The following items relate to **essential elements** of an Early Childhood STEM **definition**. Please rate the importance of each item

	Not important (1)	Neutral (2)	Somewhat Important (3)	Important (4)	Extremely Important (5)
Science, Technology, Engineering, Mathematics (1)	○	○	○	○	○
the Arts (6)	○	○	○	○	○
Innovation (8)	○	○	○	○	○
Play (9)	○	○	○	○	○
Curiosity (10)	○	○	○	○	○
Creativity, imagination (11)	○	○	○	○	○
Critical thinking (12)	○	○	○	○	○
Language of STEM (14)	○	○	○	○	○

Q14 If you want to comment, provide an explanation for your position, explain why you disagree with the majority or question why a statement is included, you can do this in the space provided. You are **encouraged** to add your thoughts and ideas

Q15 The following statements relate to **the integration of subjects/ disciplines in early childhood STEM.** Please rate your level of agreement with each statement

	Disagree (1)	Neutral (2)	Somewhat Agree (3)	Agree (4)	Strongly Agree (5)
EC STEM is any experience, routine or discussion involving a STEM discipline (EITHER science, technology, engineering, math or a combination of these disciplines) (1)	○	○	○	○	○
STEM disciplines naturally coexist and overlap in EC settings. One or more STEM discipline can arise during play and/or routine activities. (2)	○	○	○	○	○

Young children do not learn in discrete categories or subject areas. However some discipline content knowledge can be supported independently (e.g. counting or measure in mathematics), (3)	○	○	○	○	○
Exposure to the ways of thinking that characterise each of the subjects is equally important e.g. using a maths lens, engineering habits of mind (4)	○	○	○	○	○

STEM subjects taught alone could lead to more directive teaching style. Planned STEM activities are not required, and prescriptive approaches should be avoided (5)	○	○	○	○	○
The use of the project approach or long-term investigations supports integration of STEM subjects over time. (6)	○	○	○	○	○
To support children's STEM learning, an equitable inclusion of all four disciplines should be provided in the course of the term/ year, and within the curriculum. (7)	○	○	○	○	○

Integrated learning leads to a richer experience for children (8)	○	○	○	○	○

Q16 If you want to comment, provide an explanation for your position, explain why you disagree with the majority or question why a statement is included, you can do this in the space provided. You are **encouraged** to add your thoughts and ideas

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Q17 **Section 2. Early Childhood Education and STEM**

Q18 The following items relate to **elements of early childhood education to be included in EC STEM provision**. Please rate the importance of each item

	Not important (1)	Neutral (2)	Somewhat Important (3)	Important (4)	Extremely Important (5)
Play, active learning and hands-on experiences (1)	○	○	○	○	○
Children's agency, child-led approaches, respecting children's freedom to make choices (2)	○	○	○	○	○
The use of everyday, simple and open-ended materials. The use of the outdoors and nature (3)	○	○	○	○	○

Emergent approaches. Building on children's interests. Using children's interests and funds of knowledge as starting points for investigations (4)	○	○	○	○	○
Inquiry-based approaches including the use of projects and long term investigations (5)	○	○	○	○	○
The provision of play invitations and prompts to provoke inquiry and engage curiosity (6)	○	○	○	○	○
Co-construction of knowledge between adult and child (9)	○	○	○	○	○
Slow pedagogy (10)	○	○	○	○	○

The provision of opportunities to question and predict. Supports for creative thinking and meaningful problem solving (11)	○	○	○	○	○
Reflect Aistear, the early childhood curriculum framework for Ireland. (12)	○	○	○	○	○
Reflective of children’s everyday lives and a focus on the everyday nature of STEM. (13)	○	○	○	○	○
Holistic learning approaches and support for children’s holistic development (14)	○	○	○	○	○

Q19 If you want to comment, provide an explanation for your position, explain why you disagree with the majority or question why a statement is included, you can do this in the space provided. You are **encouraged** to add your thoughts and ideas

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Q20 The following items relate to the **role of the EC professional in supporting EC STEM**. Please rate the importance of the following items

	Not Important (1)	Neutral (2)	Somewhat Important (3)	Important (4)	Extremely Important (5)
Provide guided play experiences, and more structured materials or activities based on the child's STEM interests. (1)	○	○	○	○	○

Act as a play partner, co-constructor of knowledge, co-learner, collaborator, and make discoveries with the child. Respect child's ideas and initiations (2)	○	○	○	○	○
Be informed about EC STEM. Possess good knowledge of content and concepts for each discipline. Feel confident to introduce and support EC STEM. (3)	○	○	○	○	○
Be aware of progression in STEM concepts and processes. Have the ability to use these in integrated, and in single-disciplinary ways. (4)	○	○	○	○	○

Think about the world using a math- or science-lens. Model the attitudes and interests that position STEM as important, useful and connected to the world. (5)	○	○	○	○	○
Support parents in relation to STEM. Educate parents about their crucial role in their child's STEM mind-set (6)	○	○	○	○	○
Foster and build on children’s curiosity. Pose questions. Encourage wonder. Ask, I wonder questions (7)	○	○	○	○	○

Notice and recognise STEM experiences happening in the setting and STEM ideas children are interested in. Provide new experiences and resources to extend children's STEM subject knowledge. (9)	○	○	○	○	○
Make STEM learning visible. Document children's STEM learning experiences (8)	○	○	○	○	○
Model and promote the language of STEM and STEM processes such as questioning, discussing, predicting and experimenting. (11)	○	○	○	○	○
Support children to use technology in the classroom in meaningful and	○	○	○	○	○

appropriate ways (12)					
Where necessary, explicitly teach STEM concepts such as counting or life cycles (13)	○	○	○	○	○

Q21 If you want to comment, provide an explanation for your position, explain why you disagree with the majority or question why a statement is included, you can do this in the space provided. You are **encouraged** to add your thoughts and ideas

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Q22 **Section 3. STEM Knowledge, Pedagogy and Dispositions**

Q23 The following statements relate to **essential knowledge early childhood professionals require** to successfully support early childhood STEM. Please rate the importance of each item

	Not Important (1)	Neutral (2)	Somewhat Important (3)	Important (4)	Extremely Important (5)
STEM content knowledge (for example, shape, space, and number in mathematics; living things, habitats or forces in science). (1)	○	○	○	○	○
What is meant by EC STEM; definitions and core ideas from each of the STEM disciplines that are appropriate for EC. (2)	○	○	○	○	○

STEM fundamental concepts and processes (for example iterative design; problem finding and problem solving; theory generation) (3)	○	○	○	○	○
Ways of thinking that characterise STEM disciplines (4)	○	○	○	○	○
An understanding of key STEM developmental progressions. Knowledge of how to assess and plan for children's STEM progression based on interests and current knowledge. (5)	○	○	○	○	○

Appropriate STEM language including math language. Knowledge of the importance of questioning, discussing, talking with children about STEM subjects (6)	○	○	○	○	○
How to adapt or tailor STEM for the age group (babies, toddlers, young children). (7)	○	○	○	○	○
How play, inquiry-based learning and the emergent curriculum framework support EC STEM. (8)	○	○	○	○	○
Knowledge and experience of using digital technologies creatively (9)	○	○	○	○	○

Knowledge of the arts. Knowledge and experience of doing creative things themselves (10)	○	○	○	○	○
Knowledge of co-construction, how to research STEM topics WITH children, model learning as opposed to knowing everything; Foster a learning mind-set. (11)	○	○	○	○	○
Knowledge and awareness to foster approaches to STEM which ensure children's wellbeing, identity and belonging and communication are encouraged and supported within STEM learning experiences. (16)	○	○	○	○	○

Knowing where and how to access knowledge to support STEM investigation. Researching topic areas to increase knowledge and extend STEM learning experiences. (13)	○	○	○	○	○

Q24 If you want to comment, provide an explanation for your position, explain why you disagree with the majority or question why a statement is included, you can do this in the space provided. You are **encouraged** to add your thoughts and ideas

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Q25 The following statements relate to essential **pedagogical approaches** required to successfully support early childhood STEM. Please rate the importance of each item

	Not Important (1)	Neutral (2)	Somewhat Important (3)	Important (4)	Extremely Important (5)
Strong, meaningful and trusting relationships with children. (1)	○	○	○	○	○
Slow nurturing pedagogy (2)	○	○	○	○	○
Open-ended play and exploration. Playful learning (3)	○	○	○	○	○
Project and enquiry based approaches; guiding interests over days or weeks. (4)	○	○	○	○	○
Extending children's interests. Recognising and building on funds of knowledge, starting from where the child is (5)	○	○	○	○	○

Talk and discussion including questioning, discussing, talking with children about STEM subjects, math talk. (6)	○	○	○	○	○
Opportunities for collaborative learning and group work (7)	○	○	○	○	○
Adequately assess and use appropriate technology. (8)	○	○	○	○	○
Engineering design process (9)	○	○	○	○	○
Balance between structured and open-ended approaches (10)	○	○	○	○	○
Sustained shared thinking. Supporting thinking skills. (11)	○	○	○	○	○

Pedagogical documentation. Be able to observe, write learning stories and use this information as foundation for next steps in planning and expanding interests. (12)	○	○	○	○	○
Early maths pedagogical approaches. For example, maths talk, counting principles, mathematising. (13)	○	○	○	○	○
Use of block play (15)	○	○	○	○	○
Modelling STEM skills, dispositions, attitudes and habits of mind; curiosity, persistence, theory generation, research, positive attitude toward STEM, positive STEM	○	○	○	○	○

self-concept. (16)

Q26 If you want to comment, provide an explanation for your position, explain why you disagree with the majority or question why a statement is included, you can do this in the space provided. You are **encouraged** to add your thoughts and ideas

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Q27 The following statements relate to **essential attitudes and dispositions** early childhood professionals require to successfully support early childhood STEM. Please rate the importance of each item

	Not Important (1)	Neutral (2)	Somewhat Important (3)	Important (4)	Extremely Important (5)
A willingness to develop pedagogical content knowledge in STEM, view themselves as a learner (1)	○	○	○	○	○
Adaptable in the moment, flexible, open to change (2)	○	○	○	○	○
Able to say 'I don't know, let’s find out'. (3)	○	○	○	○	○
Comfort with and willing to fail or make mistakes. Willingness to step outside of their own comfort zone. (4)	○	○	○	○	○
Comfortable with mess (5)	○	○	○	○	○

Curious. Possesses a general orientation that is curious about understanding the world (7)	○	○	○	○	○
Enthusiastic, passionate (8)	○	○	○	○	○
A willingness to be playful (9)	○	○	○	○	○
Good communicator (10)	○	○	○	○	○
Happy to be with children. Find pleasure in their work. (11)	○	○	○	○	○
Have a belief in children's abilities. View of children as confident and capable learners. (12)	○	○	○	○	○
Imagination (14)	○	○	○	○	○

Interested. Wonders about things (16)	○	○	○	○	○
Observant (17)	○	○	○	○	○
Patient (19)	○	○	○	○	○
Positive disposition toward STEM, positive views on the use of technology (21)	○	○	○	○	○
Positive disposition to STEM learning themselves (22)	○	○	○	○	○
Reflective (24)	○	○	○	○	○
Resilient (25)	○	○	○	○	○
Resourceful (26)	○	○	○	○	○
Respectful, responsive attitude to children's ideas	○	○	○	○	○

and innovations (27)

Q28 If you want to comment, provide an explanation for your position, explain why you disagree with the majority or question why a statement is included, you can do this in the space provided. You are **encouraged** to add your thoughts and ideas

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Q29 Section 4. Sector-wide Support and P**rofessional** Development

Q30 The following statements relate to the most effective methods of **organising and facilitating early childhood STEM professional development**. Please rate the importance of each item

	Not important (1)	Neutral (2)	Somewhat Important (3)	Important (4)	Extremely Important (5)
Include content from all STEM disciplines in professional development i.e. Science, Technology, Engineering and Mathematics (1)	○	○	○	○	○
Include STEM concepts in professional development e.g. iterative design, generating theories, principles of counting, (2)	○	○	○	○	○
Ensure play is central. Provide examples of how disciplines can be integrated in a play environment. (3)	○	○	○	○	○

Support providers to notice and meaningfully engage with STEM already present in the daily routine, activities and curriculum. (4)	○	○	○	○	○
Learning by doing; hands-on experiences using STEM materials and processes. For example, using technology, digital artefact creation, project work. (5)	○	○	○	○	○
Time for reflection; consider what early childhood STEM looks like in their practice. (8)	○	○	○	○	○

Include opportunities for peer learning, sharing practice and analysing exemplars from practice. (9)	○	○	○	○	○
Provide multiple sessions, over months, to allow educators apply learning, to discuss practice on a number of occasions and tease out issues over time (10)	○	○	○	○	○
Tailor professional development to the context e.g. location, age group, setting type, person, characteristics of families/ community. (11)	○	○	○	○	○

Incentives for educators and supportive conditions for STEM professional development (replacement staff, paid training, time in lieu, professional development during work hours) (12)	○	○	○	○	○
Flexible delivery. Blended professional development i.e. part online, part in person. (13)	○	○	○	○	○

Provision of a variety of professional development opportunities aligned to career stage and interest. Short introductory session. Intermediate for managers and leaders. Advanced, subject-specific and accredited PD for those with a strong interest. (15)	○	○	○	○	○

Q31 If you want to comment, provide an explanation for your position, explain why you disagree with the majority or question why a statement is included, you can do this in the space provided. You are **encouraged** to add your thoughts and ideas

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Q32 The following statements relate to the most effective methods of **supporting** early childhood professionals **after STEM professional development**. Please rate the importance of each item

	Not Important (1)	Neutral (2)	Somewhat Important (3)	Important (4)	Extremely Important (5)
Provision of STEM resources and materials for settings (1)	○	○	○	○	○
Informal, one-off, community-based learning opportunities using hands-on approaches e.g. in zoo, local library, museum, as part of maths week, community garden, SFI discover centres or training from tech companies (3)	○	○	○	○	○
Build security in new knowledge and understanding through ongoing supports after formal PD e.g. mentoring, facilitated community of practice, local networks for peer collaboration and observing the practice of others. (4)	○	○	○	○	○

Provision of further online information, resources, best practice examples and self-evaluation tools, vetted by experts and easily accessible to educators. Resources with various levels of detail i.e. introductory, intermediate and advanced. (5)	○	○	○	○	○
Support-based models where changes/improvements can be shared and discussed to develop and broaden a shared language around early STEM content and pedagogies. (6)	○	○	○	○	○

Q33 If you want to comment, provide an explanation for your position, explain why you disagree with the majority or question why a statement is included, you can do this in the space provided. You are **encouraged** to add your thoughts and ideas

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Q34 What **features of organisation at different levels** need to be in place to scale up early childhood STEM professional development

	Not Important (1)	Neutral (2)	Somewhat Important (3)	Important (4)	Extremely Important (5)
A clear vision for early childhood STEM across the sector. Commitment from multiple government Departments with responsibility for EC e.g. Department of Children; Department of Education (1)	○	○	○	○	○
Government Departments to collaborate and take responsibility for the content of EC STEM professional development (2)	○	○	○	○	○

Creation of an EC STEM Inter-Departmental group. Division of roles and responsibilities including rollout and evaluation of national EC STEM professional development. (3)	○	○	○	○	○
Agreement by experts on EC STEM skills and knowledge requirements. Content of EC STEM professional development aligned with these requirements. (4)	○	○	○	○	○

Assessment of current capacity in relation to EC STEM, including; sector-wide survey; review of education inspection reports in relation to EC STEM; creation of an EC STEM expert panel. (5)	○	○	○	○	○
Established local and regional supports to facilitate EC STEM professional development events around the country i.e. Better Start; National Voluntary Childcare Organisations such as Barnardos or Early Childhood Ireland (6)	○	○	○	○	○
Inclusion of EC STEM in plans for local and regional support organisations. (7)	○	○	○	○	○

Inclusion of STEM in national EC guidelines i.e. Aistear the National Curriculum framework and Síolta the National Quality framework. (8)	○	○	○	○	○
STEM content to be included in all EC qualifications from level 5 to 8. Quality and Qualifications Ireland (QQI) and Further and Higher Education Institutions to be responsible for content of all EC initial qualifications (9)	○	○	○	○	○
Guaranteed funding, ring-fenced for specific EC STEM objectives; training, resources, ongoing supports (e.g. communities of practice, follow up training), assessment of	○	○	○	○	○

current capacity. (10)					
Provision of STEM professional development for teacher educators, mentors, inspectorate and others in support positions. (11)	○	○	○	○	○

Establish broader coalitions that enable multiple stakeholders to learn together and create a shared language and understanding i.e. educators, academics, mentors, inspectorate, curriculum bodies and EC policy makers (12)	○	○	○	○	○
Supportive STEM-informed Inspection from Tusla (The Child and Family Agency responsible for improving wellbeing and outcomes for children) and Department of Education Inspectorate (13)	○	○	○	○	○

A combination of top-down EC STEM policy and provision of EC STEM PD, coupled with bottom-up openings for sharing expertise (14)	○	○	○	○	○

Q35 If you want to comment, provide an explanation for your position, explain why you disagree with the majority or question why a statement is included, you can do this in the space provided. You are **encouraged** to add your thoughts and ideas

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Q36 As this is your **final opportunity** to share your expertise as part of the study do you have any final comments?

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Q37 Once again, I'm enormously grateful for your expertise and time. I'll be in touch with the final report before the end of the year

End of Block: Defining Early Childhood STEM

Appendix 7: Expert Profiles

Identifier	Expert Role	Practice experience	Research experience	Lecturing experience	PD Design /Delivery	STEM SIG Member	STEM Resource Development	Policy Development	0-6	6+	Number of rounds
E1	Educator	1	1	0	1	1	0	0	3-6	0	3
E2	Educator	1	0	0	1	1	0	0	3-6	0	2
E3	Educator	1	1	1	1	0	0	0	1	0	3
A1	Academic	0	0	1	0	1	0	0	1	0	3
A2	Academic	1	1	1	1	1	1	0	1	0	3
A3	Academic	1	1	1	1	0	1	0	1	0	3
A4	Academic	0	1	0	1	1	1	0	0	1	2
A5	Academic	0	1	1	0	0	0	0	0-8	0	3
S1	Support	0	0	0	0	0	1	0	1	0	3
S2	Support	1	0	0	1	0	0	0	1	0	3
S3	Support	1	0	0	0	0	0	1	1	0	2
S4	Support	1	1	0	1	0	0	0	1	0	3
P1	Policy	0	0	0	1	0	1	0	0-6	0	3
P2	Policy	1	0	0	1	0	1	0	0-6	0	3

Appendix 8: Participant Information Sheet and Consent Form.

Participant Information Sheet

Reaching consensus on the integration of STEM in ECEC settings in the Republic of Ireland.

Research Project Title: Reaching consensus on the integration of STEM in ECEC settings in the Republic of Ireland.

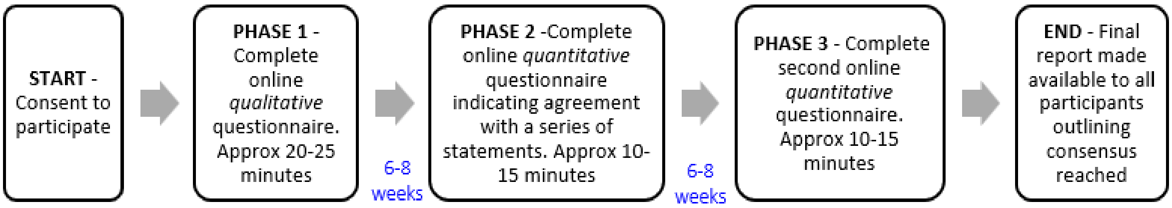
Project overview: You are being invited to take part in a research project. Before you decide whether or not to participate, it is important for you to understand why the research is being done and what it will involve. Read the following information carefully and take time to decide whether or not you wish to take part. Please ask me if there is anything that is not clear or if you would like more information (by calling 01 7009053 or emailing smeoneill1@sheffield.ac.uk). Thank you for taking the time to read this.

Project purpose: The project is being undertaken as part of a Doctorate of Education in the University of Sheffield and aims to investigate understandings of Early Childhood Science, Technology, Engineering and Mathematics (EC STEM) in the Republic of Ireland (ROI). A panel of experts will be invited to contribute their perspectives through a series of 3 questionnaires. The following research questions will guide this study; how is EC STEM understood by different stakeholders in ROI? How should STEM education be implemented in ECEC in ROI? and what, if any, professional development opportunities do educators need to meaningfully implement STEM in ECEC settings?

Why have I been chosen? This project aims to gain consensus from a panel of experts in the ROI. Due to your expertise in the subject area and/or knowledge of the Irish ECCE sector you have been invited to contribute your expert opinion.

Do I have to take part? Participation is voluntary. You will be asked to sign an online consent form before submitting each questionnaire. You may choose to not take part in the study or withdraw participation during the project. If you no longer wish to be involved in the project, you do not have to give a reason. If you wish to withdraw from the research, please contact smeoneill1@sheffield.ac.uk or call 01 7009053 and your data will be removed . Please note that by choosing to participate in this research, this will not create a legally binding agreement, nor is it intended to create an employment relationship between you and the University of Sheffield.

What will happen to me if I take part? What do I have to do? This project utilises the Delphi Framework, a method designed to obtain the most reliable consensus on a specific topic from a group of experts. It involves the completion of three questionnaires over a 3- to 4-month period. The first questionnaire is open-ended and qualitative in nature and will gather broad perspectives on issues related to EC STEM. Data are analysed and a series of statements are devised based on common understandings and perspectives that emerge from the initial questionnaires. The final two questionnaires are shorter, presenting the series of statements and requiring participants to identify their level of agreement with each one, using Likert scales. Once analysed a third set of statements will be devised reflecting a level of consensus among experts.



[1] Please note that there is a point at which it will not be possible for your data to be withdrawn from the research, as data collected in the initial questionnaire informs the next phase of the study. In this instance, participants can withdraw from any on-going or future data collection. Earlier data cannot be removed from the study but will be fully anonymised.

What are the possible disadvantages and risks of taking part?
Participation is voluntary. Questionnaires are completed independently online so while participants are a member of a panel of experts, the panel will never meet in person or online. Participants may be uncomfortable completing some sections of the questionnaire, however, sections can be skipped without explanation and there will be space for participants to qualify their answers if they feel this is necessary in the closed/ quantitative questionnaires. In addition, the researcher will be available to answer questions at each stage of the process.

Participants may experience some discomfort or frustration during the process if their opinions are not reflected in statements. All opinions, even those that are not reflected in the final consensus, will be outlined in the final report.

While every effort will be made to stick to the timeline outlined, the design of the second and third questionnaires are dependent on receiving all questionnaires within the designated timeframes. Therefore, the end of the process could be delayed.

Participants will be assigned an identifier at the start of the study to protect identity and track progress. It should be noted that the participant sample size is small, and while every effort to protect confidentiality of participants will be made, it could be possible for those intimately familiar with the Irish ECEC sector to identify participants.

What are the possible benefits of taking part? Whilst there are no immediate benefits for those people participating in the project, it is hoped that this work will help to expand the understanding of EC STEM in ROI. The information may be useful in future policy development, design of CPD or initial training and help identify key tenants of EC STEM.

Will my taking part in this project be kept confidential? All information collected about you during the course of the research will be kept strictly confidential and data will only be accessible to Sandra O'Neill and Ed D. Supervisors (listed at the bottom of page 3). Participants will be assigned an identifier at the beginning of the study and this pseudonym will be used throughout the final report. At the end of the study, the final report will be shared with you. At this point, you will be asked if you would like to be named as part of the expert panel. Specific consent for this will be obtained and your personal details will not be included unless you explicitly request this. Pseudonymised information will continue to be used in the final report.

It should be noted that confidentiality of information provided 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. In addition, the participant sample size is small, and while every effort to protect confidentiality of participants will be made, it could be possible for those intimately familiar with the Irish ECEC sector to identify participants.

What is the legal basis for processing my personal data? Some personal data will be collected as part of the research study including your name, current role, STEM expertise and work history. According to data protection legislation, I am required to inform you that the legal basis being applied in order to process your personal data is that 'processing is necessary for the performance of a task carried out in the public interest' (Article 6 (1) (e)). Further information can be found in the University's Privacy Notice https://www.sheffield.ac.uk/govern/data-protection/privacy/general'

What will happen to the data collected, and the results of the research project?
Once collected your data will be stored in password protected files on university managed devices and servers. Ed D. Supervisors from the university of Sheffield will have access to your data in pseudonymised format. The results of the research will be made available online via the White Rose eThesis website in 2023 and are likely to be published in academic journals. A copy of the final report i.e. the consensus reached by the group; and the final thesis will be shared with you.
Your data are stored for four years after the results of the research are published and then destroyed by the researcher. Identifiable personal data will be destroyed as soon as the final report is written.
Due to the nature of this research it is very likely that I or other researchers may find the data collected to be useful in answering future research questions. I will ask for your explicit consent for your data to be shared in this way.

Who is the Data Controller? The University of Sheffield will act as the Data Controller for this study. This means that the University is responsible for looking after your information and using it properly.

Who has ethically reviewed the project? This project has been ethically approved via the University of Sheffield's Ethics Review Procedure, as administered by the School of Education.

Safeguarding. The University has developed a policy for safeguarding to aim to prevent harm in research. There is recognition that research activities can have an impact in the wider community and/or external individuals. The policy is designed not only to consider wider impacts of research, but also to ensure that there are clear procedures in place for reporting and escalation, placing those who have been potentially affected in a key role in guiding how incidents or concerns are resolved. This policy is available at https://www.sheffield.ac.uk/rs/ethicsandintegrity/safeguarding

The designated safeguarding contact for this study is Emma Pearson emma.pearson@sheffield.ac.uk or Liz Chesworth e.a.chesworth@sheffield.ac.uk. If the concern or incident relates to the Designated Safeguarding Contact, or if you feel a report you have made to this Contact has not been handled in a satisfactory way, please contact the Head of the School of Education: Professor Rebecca Lawthom, r.lawthom@sheffield.ac.uk or the University's Research Ethics & Integrity Manager Lindsay Unwin, l.v.unwin@sheffield.ac.uk

What if something goes wrong and I wish to complain about the research or report a concern or incident?

If you are dissatisfied with any aspect of the research and wish to make a complaint, please contact Sandra O'Neill (call 01 7009053 or email smeoneill1@sheffield.ac.uk) in the first instance.
If you feel your complaint has not been handled in a satisfactory way you can contact the Head of the Department of the School of Education, Professor Rebecca Lawthom (call +44 114 222 8172 or email r.lawthom@sheffield.ac.uk).

If the complaint relates to how your personal data has been handled, you can find information about how to raise a complaint: https://www.sheffield.ac.uk/govern/data-protection/privacy/general

Contact for further information: To obtain further information about the project, contact

- Researcher. Sandra O'Neill smeoneill1@sheffield.ac.uk
- Research Supervisors. Emma Pearson emma.pearson@sheffield.ac.uk and Liz Chesworth e.a.chesworth@sheffield.ac.uk

You should maintain a copy of this information sheet for your records.
A copy of the consent form will also be shared with you to keep.

Thank you for considering participation in this project and do not hesitate to contact me with any questions relating to any element of the project.

Participant Consent Form

Title: *Reaching consensus on the integration of STEM in ECEC settings in the Republic of Ireland*

Please tick the appropriate boxes	**Yes**	**No**
Taking Part in the Project		
I have read and understood the project information sheet dated DD/MM/YYYY or the project has been fully explained to me. (If you will answer No to this question please do not proceed with this consent form until you are fully aware of what your participation in the project will mean.)		
I have been given the opportunity to ask questions about the project.		
I agree to take part in the project. I understand that taking part in the project will include the completion of three questionnaires over the course of 3-4 months		
I understand that by choosing to participate as a volunteer in this research, this does not create a legally binding agreement nor is it intended to create an employment relationship with the University of Sheffield.		
I understand that my taking part is voluntary and that I can withdraw from the study at any time. I understand that once the first questionnaire has been submitted this data cannot be withdrawn from the project but that I can withdraw from any on-going or future data collection; I do not have to give any reasons for why I no longer want to take part and there will be no adverse consequences if I choose to withdraw.		
How my information will be used during and after the project		
I understand my personal details such as name, phone number and email address etc. will not be revealed to people outside the project.		
I understand and agree that my words may be quoted in publications, reports, web pages, and other research outputs. I understand that I will not be named in these outputs unless I specifically request this.		
I understand and agree that ED Supervisors from the University of Sheffield will have access to this data in an pseudonymised format only if they agree to preserve the confidentiality of the information as requested in this form.		
I understand and agree that other authorised researchers may use my data in publications, reports, web pages, and other research outputs, only if they agree to preserve the confidentiality of the information as requested in this form. I understand that I will be asked to provide explicit consent for use of data in other publications		
So that the information you provide can be used legally by the researchers		
I agree to assign the copyright I hold in any materials generated as part of this project to The University of Sheffield.		

Project contact details for further information:
To obtain further information about the project, contact

- Researcher. Sandra O'Neill smeoneill1@sheffield.ac.uk
- Research Supervisors. Emma Pearson emma.pearson@sheffield.ac.uk and Liz Chesworth e.a.chesworth@sheffield.ac.uk
- Head of the Department of the School of Education. Professor Rebecca Lawthom r.lawthom@sheffield.ac.uk

Appendix 9: Final report to experts

Numerical value for each answer. 1= Not important, 2= Neutral and so on

Average amount of variability in answers between ratings from the expert panel. Higher marks signify a higher degree of disagreement.

Response stability across rounds of the Delphi study. Lower figures signify less change and greater accuracy

Topic under discussion

		1	2	3	4	5						
Aspects of Early Childhood Education that should be reflected in the provision of EC STEM		Not important	Neutral	Somewhat important	Important	Extremely important	**Mean**	**Median**	**Minimum rating**	**Standard deviation**	**Number of responses**	Response Stability
B3	Provision of opportunities to question and predict. Supports for creative thinking and meaningful problem solving	0	0	0	7.7%	92.3%	4.92	5	4	0.227	13	

Statement you are being asked to rate

Average response

Mid-range response

Lowest response for this statement

Number of panellists who answered this question

Section A – Defining STEM

Round 2 consensus & median	Essential elements of an Early Childhood STEM definition.		Not important	Neutral	Somewhat important	Important	Extremely important	**Mean**	**Median**	**Minimum rating**	**Standard deviation**	**Number of responses**	**Response stability**
4.9 ↑	A1	Science, Technology, Engineering, Math	0	0	0	0	100%	5	5	5	0.0	13	0.1
4.8 ↑	A8	Play	0	0	0	7.7%	92.3%	4.92	5	4	0.277	13	0.12
4.7 ↑	A2	Curiosity	0	0	0	7.7%	92.3%	4.92	5	4	0.277	13	0.22
4.7 ↑	A3	Creativity, imagination	0	0	0	15.4%	84.6%	4.85	5	4	0.375	13	0.15
4.8 =	A4	Critical thinking	0	0	7.7%	7.7%	84.6%	4.77	5	3	0.599	13	-0.03
4.2 ↑	A5	Language of STEM	0	0	7.7%	46.2%	46.2%	4.38	4	3	0.651	13	0.18
4.2 ↓	A7	Innovation	0	0	30.8%	23.1%	46.1%	4.15	4	3	0.898	13	-0.05
3.9 ↑	A6	the Arts	15.4%	0	0	15.4%	69.2%	4.23	5	1	1.48	13	0.33

Round 2 consensus & median		Integration of subjects/ disciplines in Early Childhood STEM.	Not important	Neutral	Somewhat important	Important	Extremely important	**Mean**	**Median**	**Minimum rating**	**Standard deviation**	**Number of responses**	**Response stability**
4.9 ↓	A10	STEM disciplines naturally coexist and overlap in EC settings. One or more STEM disciplines can arise during play and/or routine activities leading to integration.	0	0	0	15.4%	84.6%	4.85	5	4	0.375	13	-0.05
4.8 ↓	A14	The use of the project approach or long-term investigations supports integration of STEM subjects over time.	0	0	0	23.1%	76.9%	4.77	5	4	0.438	13	-0.03
4.5 ↑	A9	EC STEM is any experience, activity, routine or discussion involving a STEM discipline (**either** science, technology, engineering, math or a combination of these disciplines)	0	0	0	30.8%	69.2%	4.69	5	4	0.480	13	0.19
4.7 ↓	A11	Young children do not learn in discrete categories or subject areas. Some subject content can be supported independently (e.g., counting or measure in mathematics)	0	0	7.7%	23.1%	69.2%	4.62	5	3	0.650	13	-0.08
4.6 =	A16	Integrated learning leads to richer experiences for children	0	0	7.7%	23.1%	69.2%	4.62	5	3	0.650	13	0.02
4.3 =	A12	Exposure to the ways of thinking that characterise each of the subjects is equally important e.g. using a maths lens, engineering habits of mind	0	0	7.7%	53.8%	38.5%	4.31	4	3	0.630	13	0.01
3.2 ↑	A13	STEM subjects taught alone could lead to more directive teaching style. Planned STEM activities are not required, and prescriptive approaches should be avoided	23.1%	7.7%	7.7%	30.8%	30.8%	3.38	4	1	1.609	13	0.18

2.9 ↑	A15	To support children's STEM learning, an equitable inclusion of all four disciplines should be provided in the course of the term/ year, and within the curriculum.	23.1%	0	46.2%	15.4%	15.4%	3.00	3	1	1.354	13	0.1

Section B – Early Childhood Education and STEM

Round 2 consensus & median	Aspects of Early Childhood Education that should be reflected in the provision of EC STEM		Not important	Neutral	Somewhat important	Important	Extremely important	Mean	Median	Minimum rating	Standard deviation	Number of responses	Response stability
5 =	B1	Play, active learning and hands-on experiences.	0	0	0	0	100%	5.00	5	5	0	13	0
4.85 ↑	B5	Reflective of children's everyday lives and a focus on the everyday nature of STEM.	0	0	0	7.7%	92.3%	4.92	5	4	0.277	13	0.07
4.92 =	B9	Emergent approaches. Building on children's interests. Using children's interests as starting points for investigations	0	0	0	7.7%	92.3%	4.92	5	4	0.277	13	0
4.92 ↓	B3	Provision of opportunities to question and predict. Supports for creative thinking and meaningful problem solving	0	0	0	15.4%	84.6%	4.85	5	4	0.375	13	-0.07
4.85 =	B6	Holistic learning approaches and support for children's holistic development	0	0	0	15.4%	84.6%	4.85	5	4	0.375	13	0
5↓	B7	Children's agency, child-led approaches, respecting children's freedom to make choices	0	0	0	15.4%	84.6%	4.85	5	4	0.375	13	-0.15
4.85=	B8	The use of everyday, simple and open-ended materials. The use of the outdoors and nature	0	0	0	15.4%	84.6%	4.85	5	4	0.375	13	0
4.77 ↓	B11	The provision of play invitations and prompts to provoke inquiry, engage curiosity and creativity	0	0	0	15.4%	84.6%	4.85	5	4	0.375	13	0.08

4.85 ↓	B12	Co-construction of knowledge between adult and child	0	0	7.7%	7.7%	84.6%	4.77	5	3	0.599	13	-0.08
4.77 ↓	B2	Slow pedagogy	0	0	7.7%	15.4%	76.9%	4.69	5	3	0.630	13	-0.08
4.85 ↓	B10	Inquiry-based approaches including the use of projects and long-term investigations	0	0	7.7%	15.4%	76.9%	4.69	5	3	0.630	13	-0.16
4.30 ↑	B4	Reflect Aistear, the early childhood curriculum framework for Ireland.	0	7.7%	7.7%	7.7%	76.9%	4.54	5	2	0.967	13	0.24

Round 2 consensus & median		The role of the EC professional in relation to STEM	Not important	Neutral	Somewhat important	Important	Extremely important	**Mean**	**Median**	**Minimum rating**	**Standard deviation**	**Number of responses**	**Response stability**
5 =	B22	Foster and build on children’s curiosity. Pose questions. Encourage wonder. Ask 'I wonder' questions	0	0	0	0	100%	5	5	5	0	13	0
4.92↓	B17	Act as a play partner, co-constructor of knowledge, co-learner, collaborator, and make discoveries with the child. Respect child's ideas and initiations	0	0	0	15.4%	84.6%	4.85	5	4	0.375	13	-0.07
4.92↓	B24	Notice and recognise STEM experiences happening in the setting, STEM ideas children are interested in, their existing funds of knowledge and plan to expand these. Provide new experiences /resources to extend on children's STEM and subject knowledge.	0	0	7.7%	7.7%	84.6%	4.77	5	3	0.599	13	-0.15
4.77↓	B14	Model and promote the language of STEM and STEM processes such as questioning, discussing, predicting, and experimenting.	0	0	0	30.8%	69.2%	4.69	5	4	0.480	13	-0.08
4.69↓	B23	Make STEM learning visible. Document children's STEM learning experiences	0	0	7.7%	23.1%	69.2%	4.62	5	3	0.650	13	-0.07
4.38↑	B18	Be informed about EC STEM. Possess good knowledge content areas and concepts for each discipline. Confident to introduce support EC STEM.	0	0	0	53.9%	46.1%	4.46	5	4	0.518	13	0.08

4.46↓	B20	Think about the world using a math- or science-lens. Provide children with strong foundations by modelling the attitudes and interests that position STEM as important, useful and connected to the world.	0	0	7.7%	53.9%	38.5%	4.31	5	3	0.630	13	-0.15
4.08↑	B19	Be aware of progression in STEM concepts and processes. Be able to use these in integrated, and in single-disciplinary ways.	0	0	23.1%	38.5%	38.5%	4.15	4	3	0.800	13	0.07
4.31↓	B15	Support children to use technology in the classroom in meaningful and appropriate ways	0	7.7%	7.7%	46.1%	38.5%	4.15	4	2	0.898	13	-0.16
4.15↓	B21	Support parents in relation to STEM. Educate parents about their crucial role in their child's STEM mind-set	0	0	23.1%	46.1%	30.8%	4.08	4	3	0.770	13	-0.07
4.15↓	B13	Provide guided play experiences, and more structured materials or activities based on the child's STEM interests.	0	15.4%	15.4%	46.1%	23.1%	3.77	4	2	0.941	13	-0.38
3.38=	B16	Where necessary, explicitly teach STEM concepts such as counting or life cycles	15.4%	0	38.5%	23.1%	23.1%	3.38	3	1	1.325	13	0

Round 2 consensus & median		Essential knowledge early childhood professionals require to successfully support early childhood STEM.	Not important	Neutral	Somewhat important	Important	Extremely important	Mean	Median	Minimum rating	Standard deviation	Number of responses	Response stability
4.9 =	C8	How play, inquiry-based learning and the emergent curriculum framework support EC STEM.	0	0	0	15.4%	84.6%	4.85	5	4	0.375	13	-0.05
4.77↓	C12	Knowledge of co-construction, how to research STEM topics with children, model learning as opposed to knowing everything; Foster a learning mind-set.	0	0	0	30.8%	69.2%	4.69	5	4	0.480	13	-0.08
4.9↓	C7	How to adapt or tailor STEM for age group (babies, toddlers, young children).	0	0	0	38.5%	61.5%	4.62	5	4	0.506	13	-0.28
3.85↑	C11	Knowledge and awareness to foster approaches to STEM which ensure children's wellbeing, identity and belonging and communication are encouraged and supported within STEM learning experiences.	0	0	7.7%	23.1%	69.2%	4.62	5	3	0.650	13	0.77
4.31↑	C13	Knowing where and how to access knowledge to support STEM investigation. Researching topic areas to increase knowledge and extend STEM learning experiences.	0	0	0	53.9%	46.1%	4.46	4	4	0.518	13	0.15
4.31↑	C5	An understanding of key STEM developmental progressions. Knowledge of how to assess and plan for children's STEM progression based on interests and current knowledge.	0	0	7.7%	38.5%	53.9%	4.46	5	3	0.660	13	0.15
4.62↓	C6	Appropriate STEM language including math language. Knowledge of the importance of questioning, discussing, talking with children about STEM subjects	0	0	7.7%	46.1%	46.1%	4.38	4	3	0.650	13	-0.24

Round 2 consensus & median	**Essential knowledge early childhood professionals require to successfully support early childhood STEM.**		Not important	Neutral	Somewhat important	Important	Extremely important	**Mean**	**Median**	**Minimum rating**	**Standard deviation**	**Number of responses**	**Response stability**
4.15=	C1	STEM content knowledge (e.g., shape, space, and number in mathematics; living things, habitats or forces in science).	0	0	7.7%	69.2%	23.1%	4.15	4	3	0.554	13	0
4.15=	C2	What is meant by EC STEM; definitions and core ideas from each STEM discipline that are appropriate for EC.	0	0	15.4%	53.9%	30.8%	4.15	4	3	0.688	13	0
4.08=	C10	Knowledge of the arts. Knowledge and experience of doing creative things themselves	0	0	23.1%	46.1%	30.8%	4.08	4	3	0.759	13	0
4.38↑	C4	Ways of thinking that characterise STEM disciplines.	0	7.7%	15.4%	38.5%	38.5%	4.08	4	2	0.954	13	-0.3
3.46↓	C9	Knowledge and experience of using digital technologies creatively.	0	7.7%	23.1%	38.5%	30.8%	3.92	4	2	0.954	13	0.46
3.69↓	C3	STEM fundamental concepts and processes (for example iterative design; problem finding and problem solving; theory generation)	0	7.7%	38.5%	38.5%	15.4%	3.62	4	2	0.869	13	-0.07

Round 2 consensus & median		Essential pedagogical approaches professionals require to successfully support EC STEM.	Not important	Neutral	Somewhat important	Important	Extremely important	**Mean**	**Median**	**Minimum rating**	**Standard deviation**	**Responses**	**Response stability**
5=	C15	Open-ended play and exploration. Playful learning	0	0	0	0	100%	5.00	5	5	0	13	0
4.85↑	C13	Strong, meaningful and trusting relationships with children.	0	0	0	7.7%	92.3%	4.92	5	4	0.277	13	0.07
4.69↑	C17	Extending children's interests. Recognising and building on funds of knowledge, starting from where the child is	0	0	7.7%	0	92.3%	4.85	5	3	0.554	13	0.16
4.69↑	C24	Pedagogical documentation. Be able to observe, write learning stories for next steps in planning and expanding interests.	0	0	0	23.1%	76.9%	4.77	5	4	0.438	13	0.08
4.85↓	C27	Modelling STEM skills, dispositions, attitudes, habits of mind; curiosity, persistence, theory generation, positive STEM self-concept.	0	0	15.4%	0	84.6%	4.69	5	3	0.751	13	-0.16
4.85↓	C18	Talk and discussion including questioning, discussing, talking with children about STEM subjects, math talk.	0	0	7.7%	15.4%	76.9%	4.69	5	3	0.630	13	-0.16
4.69=	C14	Slow nurturing pedagogy	0	0	7.7%	15.4%	76.9%	4.69	5	3	0.630	13	0
4.62=	C23	Sustained shared thinking. Supporting thinking skills.	0	0	15.4%	7.7%	76.9%	4.62	5	3	0.767	13	0
4.9↓	C19	Provide opportunities for collaborative learning. Planning for group work.	0	7.7%	0	15.4%	76.9%	4.62	5	2	0.869	13	-0.28
4.85↓	C26	Use of block play	0	0	7.7%	30.8%	61.5%	4.54	5	3	0.660	13	-0.31

4.69↓	C16	Project/enquiry-based approaches; guiding interests over days or weeks.	0	7.7%	0	30.8%	61.5%	4.46	5	2	0.877	13	-0.23
4.38↓	C25	Early maths pedagogical approaches. For example, maths talk, counting principles, mathematising.	0	7.7%	7.7%	46.1%	38.5%	4.15	4	2	0.898	13	-0.23
4.38↓	C20	Adequately assess and use appropriate technology.	0	7.7%	15.4%	38.5%	38.5%	4.06	4	2	0.954	13	-0.32
4.31↑	C22	Balance between structured and open-ended approaches	0	23.1%	0	23.1%	53.8%	4.06	5	2	1.255	13	-0.25
4.07↑	C21	Engineering design process (EDP)	7.7%	7.7%	30.8%	46.1%	7.7%	3.38	4	1	1.043	13	-0.69

Round 2 consensus & median	Essential dispositions/ attitudes EC professionals require to successfully support EC STEM.		Not important	Neutral	Somewhat important	Important	Extremely important	**Mean**	**Median**	**Minimum rating**	**Standard deviation**	**Number of responses**	**Response stability**
5=	C38	Happy to be with children. Find pleasure in their work.	0	0	0	0	100%	5.00	5	5	0	13	0
5=	C39	Have a belief in children's abilities. View of children as confident and capable learners.	0	0	0	0	100%	5.00	5	5	0	13	0
4.85↑	C30	Adaptable in the moment, flexible, open to change	0	0	0	0	100%	5.00	5	5	0	13	0.15
4.53↑	C36	A willingness to be playful.	0	0	0	0	100%	5.00	5	5	0	13	0.47
5=	C42	Observant	0	0	0	0	100%	5.00	5	5	0	13	0
4.9↑	C31	Able to say 'I don't know, let’s find out'.	0	0	0	0	100%	5.00	5	5	0	13	0.1
5↓	C49	Respectful, responsive attitude to children's ideas and innovations	0	0	0	7.7%	92.3%	4.92	5	4	0.277	13	-0.08
4.9↑	C37	Good communicator	0	0	0	7.7%	92.3%	4.92	5	4	0.277	13	-0.02
4.9↑	C43	Patient	0	0	0	7.7%	92.3%	4.92	5	4	0.277	13	-0.02
4.85↑	C28	A willingness to develop pedagogical content knowledge in STEM, view themselves as a learner	0	0	0	7.7%	92.3%	4.92	5	4	0.277	13	0.07
4.85↑	C32	Comfort with and willing to fail or make mistakes. Willingness to step outside of their own comfort zone.	0	0	0	7.7%	92.3%	4.92	5	4	0.277	13	0.07
4.85=	C41	Interested. Wonders about things.	0	0	0	15.4%	84.6%	4.85	5	4	0.375	13	0
4.9↓	C46	Reflective	0	0	0	15.4%	84.6%	4.85	5	4	0.375	13	-0.05

4.54↑	C45	Positive disposition to STEM learning themselves	0	0	0	15.4%	84.6%	4.85	5	4	0.375	13	0.31
4.85↓	C34	Curious. Possesses a general orientation that is curious about understanding the world	0	0	0	23.1%	76.9%	4.77	5	4	0.438	13	-0.08

Round 2 consensus & median		**Essential dispositions/ attitudes EC professionals require to successfully support EC STEM.**	Not important	Neutral	Somewhat important	Important	Extremely important	**Mean**	**Median**	**Minimum rating**	**Standard deviation**	**Number of responses**	**Response stability**
4.00↑	C48	Resourceful	0	0	0	23.1%	76.9%	4.77	5	4	0.438	13	0.77
4.85↓	C40	Imagination	0	0	0	30.8%	69.2%	4.69	5	4	0.480	13	-0.16
4.62↓	C44	Positive disposition toward STEM, positive views on the use of technology	0	0	0	30.8%	69.2%	4.69	5	4	0.480	13	0.07
4.00↑	C35	Enthusiastic. Passionate	0	0	0	38.5%	61.5%	4.62	5	4	0.506	13	0.62
4.00↑	C47	Resilient	0	0	0	38.5%	61.5%	4.62	5	4	0.506	13	0.62
4.00↓	C33	Comfortable with mess	0	0	7.7%	30.8%	61.5%	4.54	5	3	0.660	13	0.54

Section D – Support and Professional Development

Round 2 consensus & median	Effective methods of organising and facilitating EC STEM professional development.		Not important	Neutral	Somewhat important	Important	Extremely important	**Mean**	**Median**	**Minimum rating**	**Standard deviation**	**Number of responses**	**Response stability**
5=	D3	Ensure play is at the forefront of how STEM is considered in practice. Provide examples of how subjects can be integrated in a play environment	0	0	0	7.7%	92.3%	4.92	5	4	0.277	13	0
4.9=	D4	Support providers to notice and meaningfully engage with STEM already present in the daily routine, activities, and curriculum.	0	0	0	7.7%	92.3%	4.92	5	4	0.277	13	0.02
4.15↑	D6	Time for reflection. Consider what early childhood STEM looks like in their practice.	0	0	0	7.7%	92.3%	4.92	5	4	0.277	13	0.77
4.78=	D10	Incentives for educators and supportive conditions for STEM professional development (replacement staff, paid training, time in lieu, professional development during work hours)	0	0	0	23.1%	76.9%	4.77	5	4	0.438	13	-0.01
4.62↓	D5	Learning by doing with hands-on experiences using STEM materials and processes. For example, using technology, digital artefact creation, project work	0	0	0	23.1%	76.9%	4.77	5	4	0.438	13	0.15
4.78↓	D7	Include opportunities for peer learning, sharing practice and analysing exemplars from practice.	0	0	0	30.8%	69.2%	4.69	5	4	0.480	13	-0.13
4.85↓	D8	Provide multiple sessions, over months, to allow educators apply learning, to discuss practice on a number of occasions and tease out issues over time	0	0	7.7%	15.4%	76.9%	4.69	5	3	0.630	13	-0.16

4.54=	D11	Flexible delivery. Blended professional development i.e. part online, part in person.	0	0	7.7%	30.8%	61.5%	4.54	5	3	0.660	13	0
4.00↑	D12	Provision of a variety of professional development opportunities aligned to career stage and interest. Short introductory session for all. Intermediate professional development for managers and leaders. Advanced, subject-specific and accredited professional development for those with a strong interest.	0	0	15.4%	46.2%	38.5%	4.23	4	3	0.725	13	0.23

	Effective methods of organising and facilitating EC STEM professional development.		Not important	Neutral	Somewhat important	Important	Extremely important	**Mean**	**Median**	**Minimum rating**	**Standard deviation**	**Number of responses**	**Response stability**
4.38↓	D9	Tailor professional development to the context e.g. location, age group, setting type, person, characteristics of families/ community.	7.7%	0	0	46.2%	46.2%	4.23	4	1	1.091	13	-0.15
4.23↓	D1	Include content from all STEM disciplines in professional development i.e. Science, Technology, Engineering and Mathematics	0	0	15.4%	53.8%	30.8%	4.15	4	2	0.688	13	-0.18
4.15↓	D2	Include STEM concepts in professional development e.g., iterative design, generating theories, principles of counting, problem finding and problem solving, mathematising	0	7.7%	23.1%	53.8%	15.4%	3.77	4	3	0.832	13	-0.38

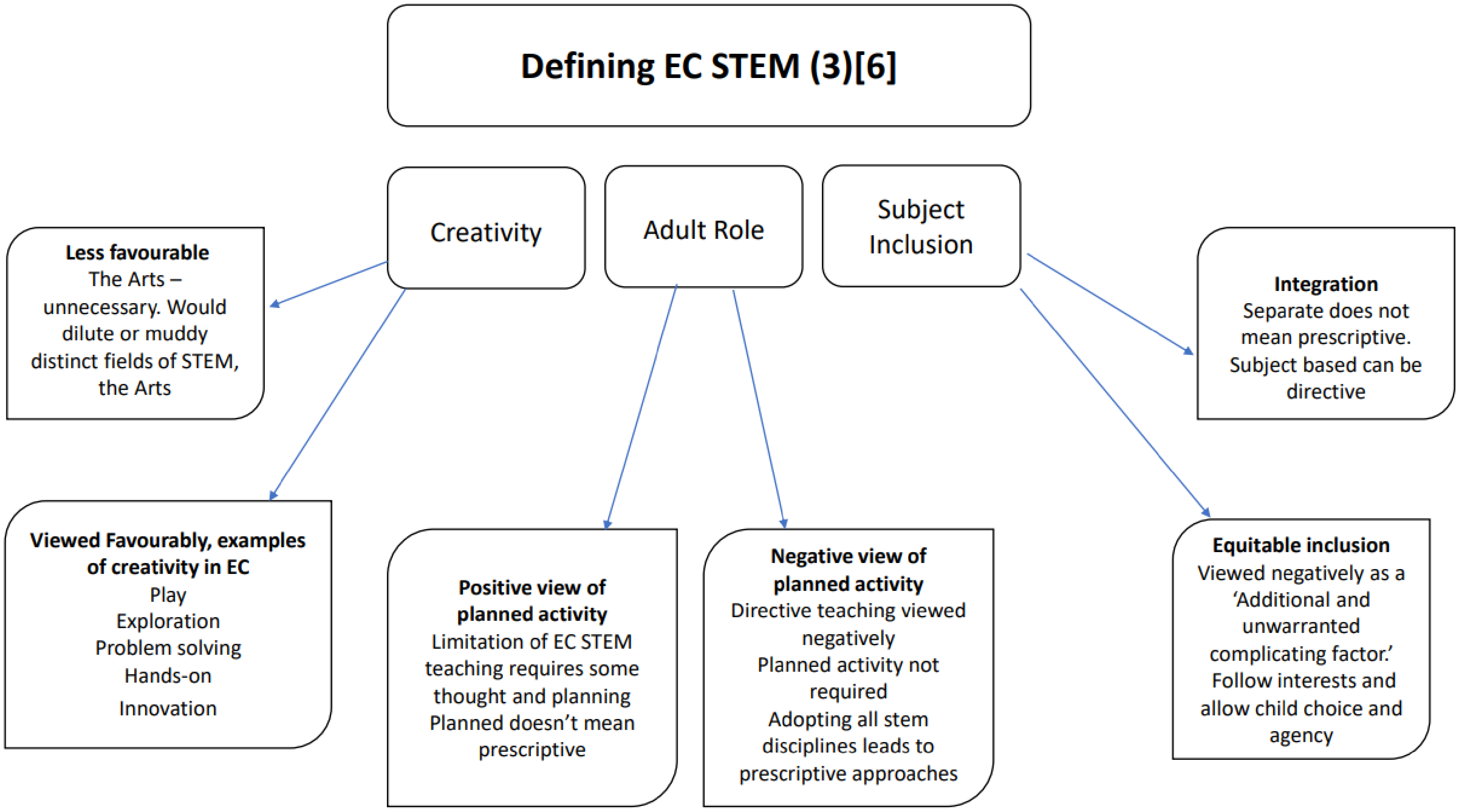
Round 2 consensus & median	Effective methods of supporting EC professionals after STEM professional development.		Not important	Neutral	Somewhat important	Important	Extremely important	**Mean**	**Median**	**Minimum rating**	**Standard deviation**	**Number of responses**	**Response stability**
4.69↓	D16	Build security in new knowledge and understanding through ongoing supports after formal PD e.g. mentoring, facilitated community of practice, local networks for peer collaboration and observing the practice of others.	0	0	7.7%	30.8%	61.6%	4.54	5	3	0.660	13	-0.15
4.62↓	D17	Provision of further online information, resources, best practice examples and self-evaluation tools, vetted by experts and easily accessible to educators. Resources with various levels of detail i.e., introductory, intermediate and advanced.	0	0	7.7%	30.8%	61.6%	4.54	5	3	0.660	13	-0.08
4.62↓	D18	Support-based models where changes/ improvements can be shared and discussed to develop and broaden a shared language around early STEM content and pedagogies.	0	0	7.7%	69.3%	23.1%	4.15	4	3	0.554	13	-0.47
4.15↓	D14	Informal, one-off, community-based learning opportunities using hands-on approaches e.g., in zoo, local library, museum, as part of maths week, community garden, SFI discover centres or training from tech companies	0	0	23.1%	53.9%	23.1%	4.00	4	3	0.707	13	-0.15
3.85↓	D13	Provision of STEM resources and materials for settings to support application of learning from professional development opportunities	0	0	46.2%	38.5%	15.4%	3.69	4	3	0.751	13	-0.16

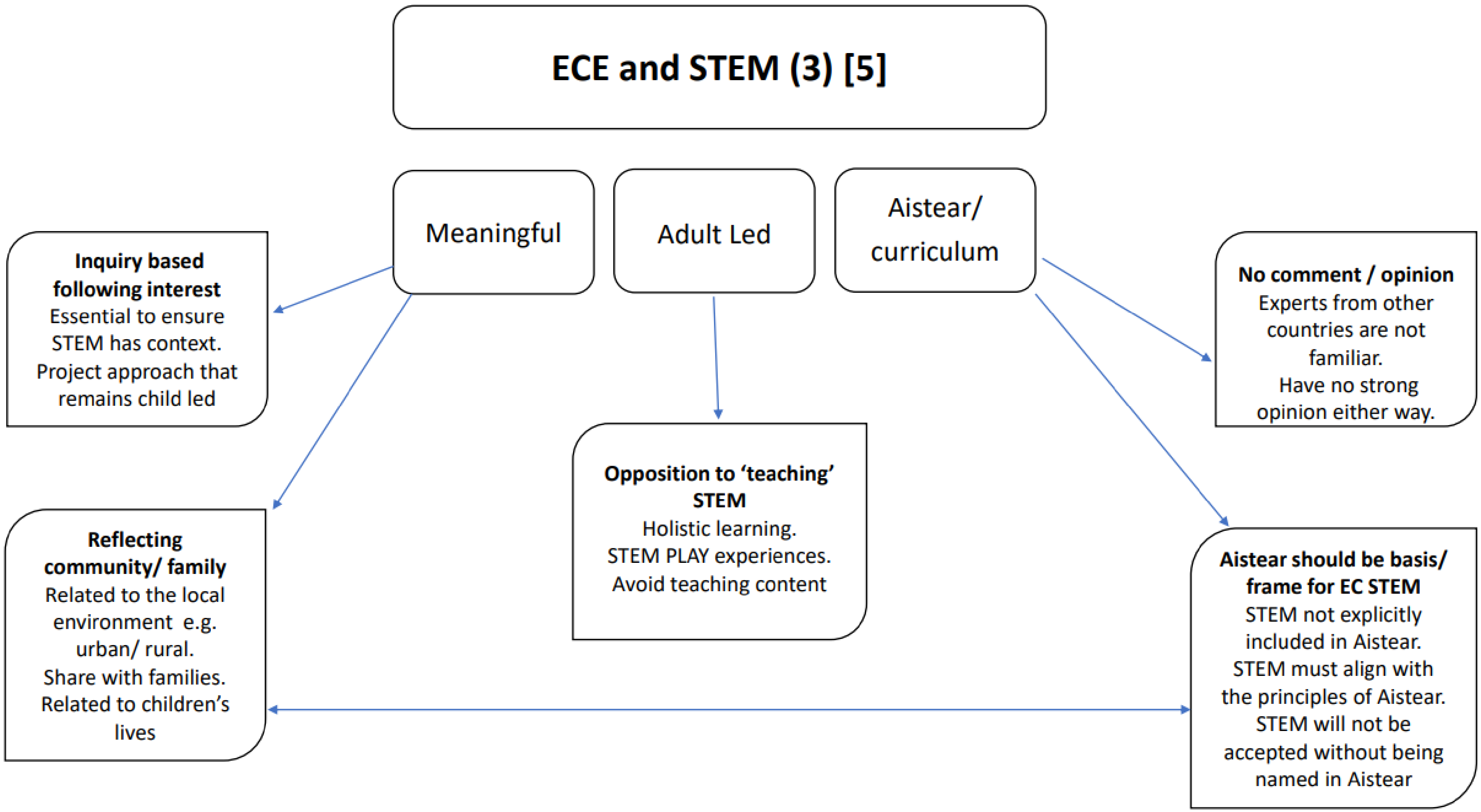
Round 2 consensus & median		Features of organisation that need to be in place to scale up EC STEM professional development.	Not important	Neutral	Somewhat important	Important	Extremely important	**Mean**	**Median**	**Minimum rating**	**Standard deviation**	**Number of responses**	**Response stability**
4.58↓	D19	A clear vision for early childhood STEM across the sector. Commitment from multiple government Departments with responsibility for EC e.g., Department of Children; DOE	0	0	7.7%	38.5%	53.9%	4.46	5	3	0.660	13	-0.12
4.82↓	D29	Provision of STEM professional development for teacher educators, mentors, inspectorate, and others in support positions.	0	0	7.7%	46.2%	46.2%	4.38	4	3	0.650	13	-0.44
4.50↓	D30	Establish broader coalitions that enable multiple stakeholders to learn together and create a shared language and understanding i.e., educators, academics, mentors, inspectorate, curriculum bodies and EC policy makers	0	0	0	61.6%	38.5%	4.38	4	3	0.506	13	-0.12
4.66↓	D26	Inclusion of STEM in national early childhood guidelines i.e., Aistear and Síolta.	0	7.7%	7.7%	30.8%	53.9%	4.31	5	2	0.947	13	-0.35
4.72↓	D28	Guaranteed funding, ring-fenced for specific EC STEM objectives; training, resources, ongoing supports (e.g., communities of practice, follow up training), assessment of current capacity.	0	0	15.4%	38.5%	46.2%	4.31	4	3	0.751	13	-0.41
4.33↓	D22	Agreement by experts on early childhood STEM skills and knowledge requirements. Content of early childhood STEM professional development to be aligned with these requirements.	7.7%	0	15.4%	30.8%	46.2%	4.08	4	1	1.187	13	-0.25
4.36↓	D32	A combination of top-down EC STEM policy and provision of EC STEM PD, coupled with bottom-up openings for sharing expertise.	7.7%	0	15.4%	30.8%	46.2%	4.08	4	1	1.187	13	-0.28

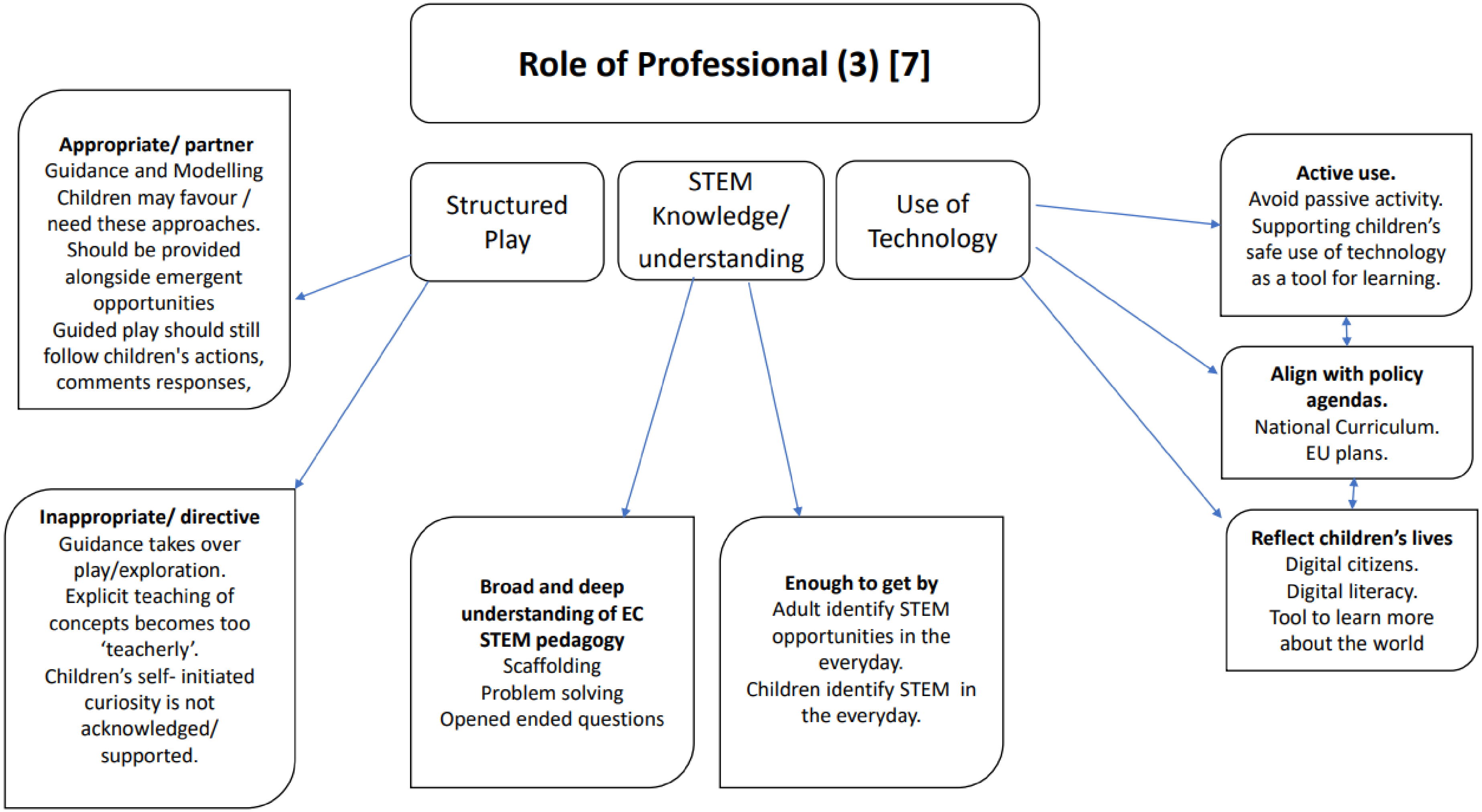
Round 2 consensus & median	Features of organisation that need to be in place to scale up EC STEM professional development.		Not important	Neutral	Somewhat important	Important	Extremely important	**Mean**	**Median**	**Minimum rating**	**Standard deviation**	**Number of responses**	**Response stability**
4.72↓	D27	STEM content to be included in all initial professional education for early childhood from level 5 to 8. Quality and Qualifications Ireland (QQI) and Further and Higher Education Institutions to be responsible for content of all early years education initial qualifications	7.7%	7.7%	15.4%	15.4%	53.9%	4.00	4	1	1.354	13	-0.72
4.46↓	D25	Inclusion of early childhood STEM in plans for local and regional support organisations.	0	0	23.1%	53.9%	23.1%	4.00	4	3	0.707	13	-0.46
4.36↓	D24	Established local and regional supports will facilitate early childhood STEM professional development events around the country i.e., Better Start; National Voluntary Childcare Organisations such as Barnardos or Early Childhood Ireland	0	7.7%	15.4%	53.9%	23.1%	3.92	4	2	0.862	13	-0.44
4.33↓	D21	Creation of an early Childhood STEM Inter-Departmental group. Division of roles and responsibilities including rollout and evaluation of national early childhood STEM professional development	7.7%	0	15.4%	46.2%	30.8%	3.92	4	1	1.115	13	-0.41
4.27↓	D23	Assessment of current capacity in relation to early childhood STEM, including but not limited to; sector-wide survey; review of education inspection reports in relation to early childhood STEM; creation of an early childhood STEM expert panel.	0	0	38.5%	38.5%	23.1%	3.85	4	3	0.800	13	-0.42

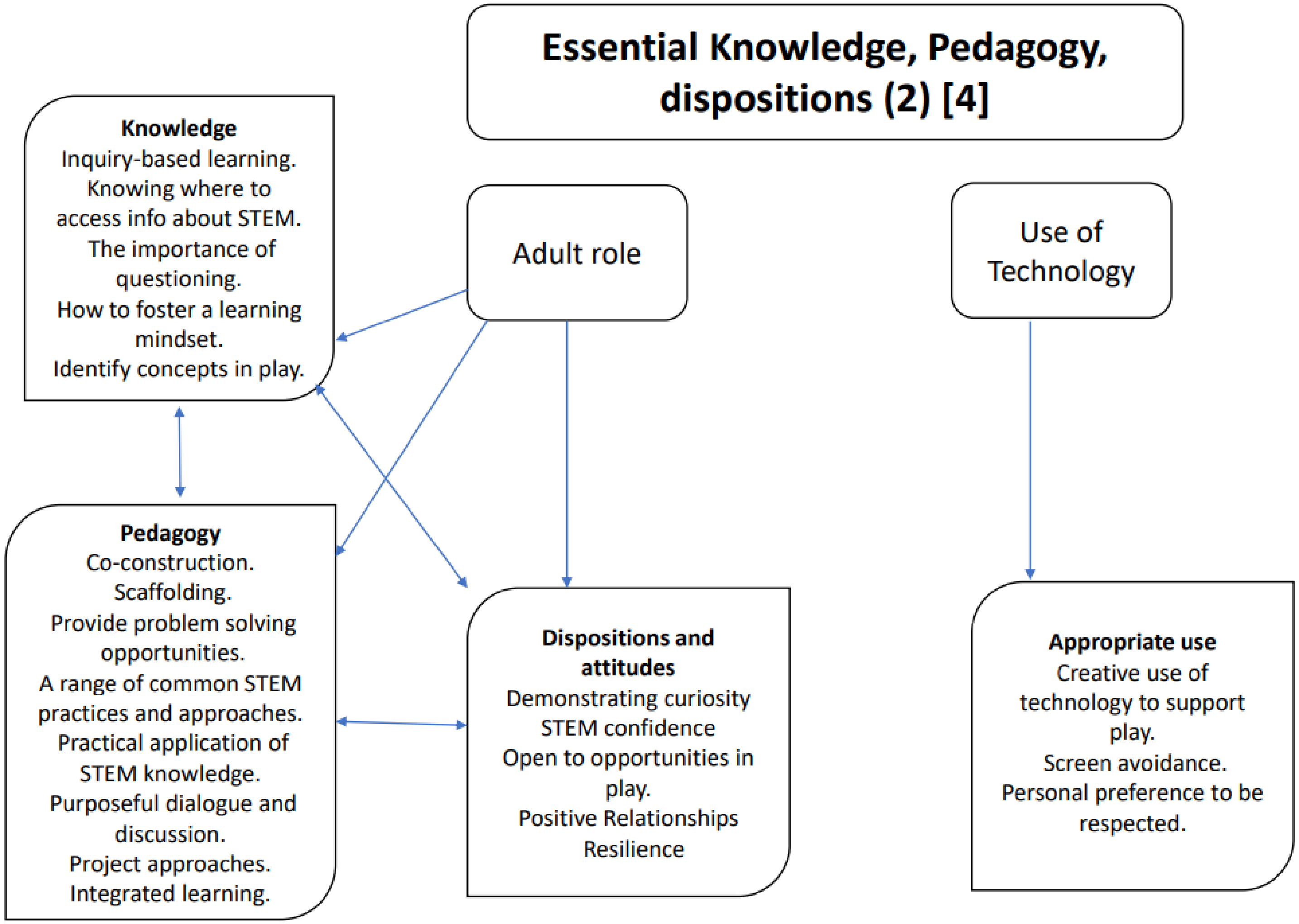
4.27↓	D31	Supportive STEM-informed Inspection from Tusla (The Child and Family Agency responsible for improving wellbeing and outcomes for children) and Department of Education Inspectorate	0	15.4%	7.7%	53.9%	23.1%	3.85	4	2	0.987	13	-0.42
4.42↓	D20	Government Departments to collaborate and take responsibility for the content of early childhood STEM professional development	7.7%	0	30.8%	30.8%	30.8%	3.77	4	1	1.165	13	-0.65

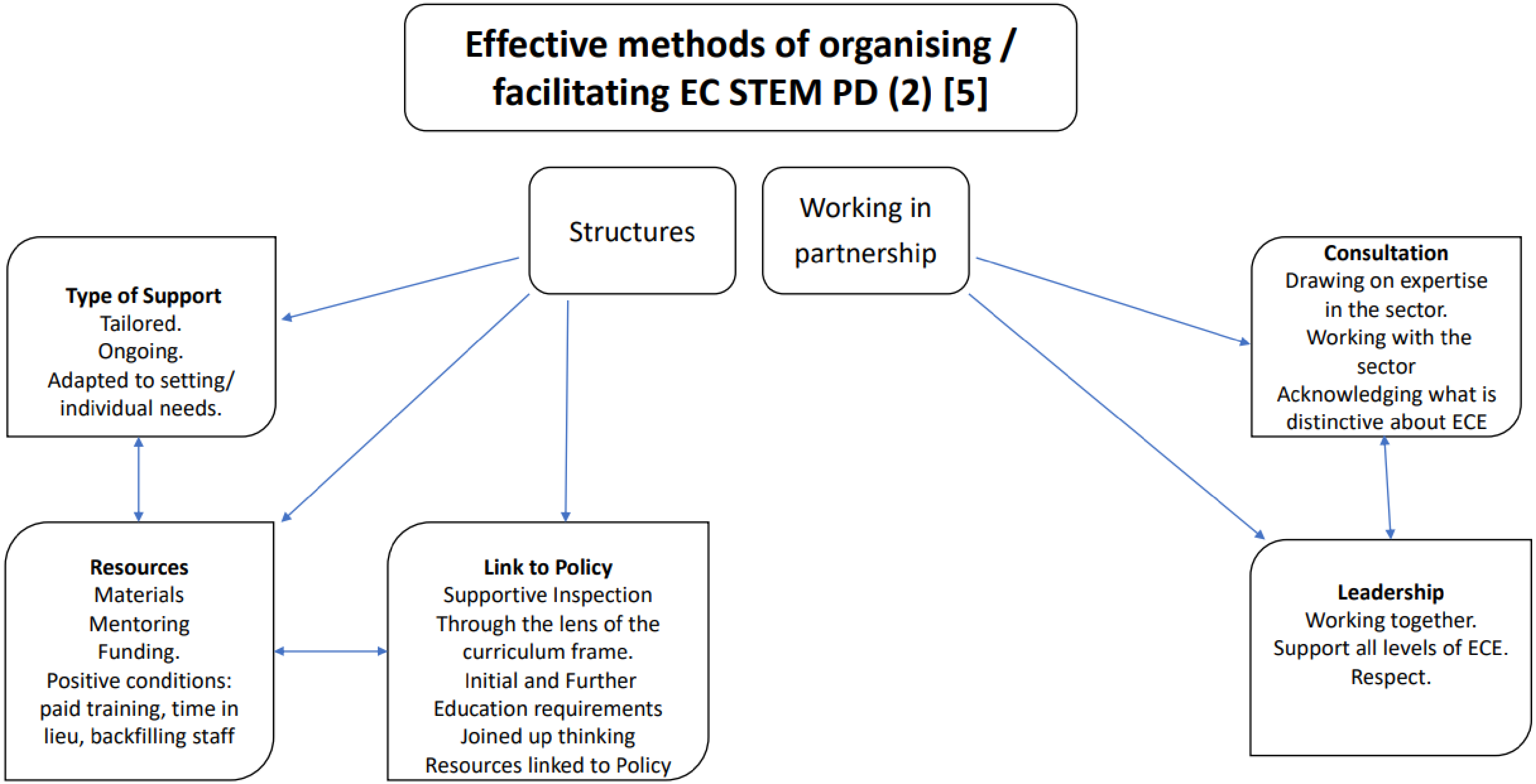
Appendix 10: Initial Themes and Codes




ECE and STEM (3) [5]
Meaningful
Adult Led
Aistear/ curriculum
Inquiry based following interest
Essential to ensure STEM has context.
Project approach that remains child led
Reflecting community/ family
Related to the local environment e.g. urban/ rural.
Share with families.
Related to children's lives
Opposition to 'teaching' STEM
Holistic learning.
STEM PLAY experiences.
Avoid teaching content
No comment / opinion
Experts from other countries are not familiar.
Have no strong opinion either way.
Aistear should be basis/ frame for EC STEM
STEM not explicitly included in Aistear.
STEM must align with the principles of Aistear.
STEM will not be accepted without being named in Aistear


Role of Professional (3) [7]
Structured Play
STEM Knowledge/ understanding
Use of Technology
Appropriate/ partner
Guidance and Modelling
Children may favour / need these approaches.
Should be provided alongside emergent opportunities
Guided play should still follow children's actions, comments responses,
Inappropriate/ directive
Guidance takes over play/exploration.
Explicit teaching of concepts becomes too 'teacherly'.
Children's self- initiated curiosity is not acknowledged/ supported.
Broad and deep understanding of EC STEM pedagogy
Scaffolding
Problem solving
Opened ended questions
Enough to get by
Adult identify STEM opportunities in the everyday.
Children identify STEM in the everyday.
Active use.
Avoid passive activity.
Supporting children's safe use of technology as a tool for learning.
Align with policy agendas.
National Curriculum.
EU plans.
Reflect children's lives
Digital citizens.
Digital literacy.
Tool to learn more about the world


Essential Knowledge, Pedagogy, dispositions (2) [4]
Knowledge
Inquiry-based learning.
Knowing where to access info about STEM.
The importance of questioning.
How to foster a learning mindset.
Identify concepts in play.
Adult role
Use of Technology
Pedagogy
Co-construction.
Scaffolding.
Provide problem solving opportunities.
A range of common STEM practices and approaches.
Practical application of STEM knowledge.
Purposeful dialogue and discussion.
Project approaches.
Integrated learning.
Dispositions and attitudes
Demonstrating curiosity
STEM confidence
Open to opportunities in play.
Positive Relationships
Resilience
Appropriate use
Creative use of technology to support play.
Screen avoidance.
Personal preference to be respected.


Effective methods of organising / facilitating EC STEM PD (2) [5]
Structures
Working in partnership
Type of Support
Tailored.
Ongoing.
Adapted to setting/ individual needs.
Resources
Materials
Mentoring
Funding.
Positive conditions: paid training, time in lieu, backfilling staff
Link to Policy
Supportive Inspection
Through the lens of the curriculum frame.
Initial and Further Education requirements
Joined up thinking
Resources linked to Policy
Consultation
Drawing on expertise in the sector.
Working with the sector
Acknowledging what is distinctive about ECE
Leadership
Working together.
Support all levels of ECE.
Respect.

Appendix 11: Acronyms

CK	Content Knowledge
CPD	Continuing Professional Development
DCEDIY	Department of Children, Equality, Disability, Integration and Youth
DE	Department of Education (Ireland, from 2020. Previously called DES)
DEIS	Delivering Equality of Opportunity in Schools.
DES	Department of Education and Skills (Ireland, until 2020 when it was renamed DE)
EC STEM	Early Childhood Science Technology Engineering and Mathematics
EC	Early Childhood
ECE	Early Childhood Education
ECEC	Early Childhood Education and Care
EYEI	Early Years Education Inspection
GCK	General Content Knowledge
GOI	Government of Ireland
ITE	Initial Teacher Education
I-STEM	Integrated Science, Technology, Engineering and Mathematics
ITE	Initial Teacher Education
NCCA	National Council for Curriculum and Assessment
NGO	Non-governmental organisation, Typically not for profit
NSAI	National Síolta Aistear Initiative
PCK	Pedagogical Content Knowledge
PD	Professional Development
ROI	Republic of Ireland
RTA	Reflexive Thematic Analysis
STEAM	Science Technology Engineering the Arts and Mathematics
STEM	Science Technology Engineering and Mathematics

Appendix 12: Glossary

Aistear	The Early Childhood Curriculum Framework for the Republic of Ireland
DEIS	Delivering Equality of Opportunity in Schools (DEIS). This term is used to describe areas of educational disadvantage that are entitled additional government supports. These supports are not currently extended to EC services
Early years education focused inspections (EYEFI)	A separate inspection system for settings offering the free preschool year. This is managed by the department of education and focuses on children's learning (as opposed to Tusla inspections, see below)
I-STEM	Integrated Science Technology Engineering and Mathematics
Pobal	A state-sponsored organisation in Ireland with responsibility for administering and managing government and EU funding aimed at supporting social inclusion and addressing social disadvantage in the country.
Siolta	The Early Childhood Quality Framework in the Republic of Ireland
STEAM	Science Technology Engineering the Arts and Mathematics
STEM Education Policy Statement	Overarching policy document that aims to integrate STEM into all levels of Education in ROI and beyond.
STEM	Science Technology Engineering and Mathematics
Tusla	The Child and Family Agency in Ireland responsible for improving wellbeing and outcomes for children. Early years settings in ROI must register with Tusla and are subject to health and safety inspections. Tusla has legislative powers and can force the closure of settings who do not comply with regulations

Appendix 13: Consensus Definition

In this study, Delphi Statements are deemed to have reached

1. **'strong consensus'** if >90% of participants rated them in the top level of importance, OR >80% of participants rated using the top response AND 100% of participants used the top 2 levels of importance.
2. **'consensus'** if >80% of participants rated them in the top level of importance, AND >90% in the top 2.
3. **'low consensus'** if statements do not meet the above criteria for strong consensus or consensus.
4. '**consensus of disagreement'** if >90% of participants rated them in the bottom level, OR if >80% of participants rated using the bottom response AND 100% of participants used the bottom 2 responses.

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