Higher-Order Thinking in Early Childhood Education and Care

Mediating young children's higher-order thinking skills. The role of mathematics, coding toys and educators

by

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Acknowledgements

Right at the beginning of this journey, during the first few days, I came across a drawing, a humorous representation of the PhD trajectory. The drawing consisted of two vignettes. In the first, a man on a bicycle was depicted on the left with a slightly uphill but nonetheless linear path lying before him up to the chequered flag on the right, which symbolised the achievement of the doctorate. This first cartoon was entitled ‘Your plan’. The second cartoon, entitled ‘Reality’, showed the same man on a bicycle to the left with the chequered flag to the right. In the middle, however, there was no longer an almost horizontal line but a series of mountains, valleys, lakes, obstacles of various types and bad weather. While the second vignette is, admittedly, a fairly accurate reflection of reality, it fails to capture how exciting, challenging, educational, and enriching the doctoral undertaking actually is. Despite the difficulties that arose, at no time did I regret my decision.

I would therefore like to thank my three supervisors, Professor Natalia Kucirkova, Professor Ingunn Størksen and Associate Professor Tuula Helka Skarstein. Thank you so much, Natalia, for accompanying and supporting me on this journey. Your profound knowledge and experience in the field have been a source of immense inspiration, and I am grateful to have had the opportunity to learn from your supervision. Ingunn and Tuula, you have been incredibly supportive to me, both academically and personally, and it has been a pleasure to work with you.

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Thanks also to my family in Italy. I address a special thought to my parents: I wish you were here to share this milestone with me. I am sure that you would be very proud of my achievement.

Summary

Background: Higher-order thinking skills are those skills that allow children to not only acquire but also to process knowledge as they prepare to meet the challenges posed by the 21st century. Research to date has highlighted various examples of these skills; this thesis focuses on existing approaches to higher-order thinking, including critical thinking, problem-solving and transfer.

Research attests that considerable emphasis is placed on these skills at school level but less so in early childhood education and care (ECEC). Nonetheless, to foster young children's ability to develop these skills, we must deepen our knowledge and understanding of higher-order thinking skills as they pertain to the ECEC stage.

The research reported herein adhered to the qualitative research tradition, specifically drawing from the conceptual framework of hermeneutics. The primary objective was to understand rather than clarify the approach to higher-order thinking skills in ECEC and to prioritise interpretation over prediction. To this end, I investigated educators' perceptions and how different situations in ECEC may be interpreted in light of their potential to foster higher-order thinking skills. In play-based environments, such as that which is characteristic of ECEC, mathematics-based games and coding toys are investigated as two possible means of nurturing those skills. The theoretical approach is informed by Vygotsky's theory of mediated activities, which includes mathematics, coding toys and human beings as mediators.

Aims: The aim of this thesis is to learn more about higher-order thinking skills in ECEC and to offer a new theoretical perspective that envisages a significant role for mathematics, coding toys and educators in the process of mediating higher mental functions. Accordingly, Study I investigated ECEC educators' perceptions of critical thinking; Study II aimed to investigate educators' perspectives on mathematics and the

connection between mathematics and higher-order thinking skills; and Study III explored educators' views on and strategies for the use of coding toys and their corresponding outputs in terms of the skills that children developed.

Methods: Studies I and II are based on the analysis of 10 semi-structured interviews with Norwegian educators from three different ECEC centres. Eight were pedagogical leaders, and two were ECEC educators working with children with additional needs. The participants had an average of 17 years of experience in ECEC (minimum 1.5; maximum 35 years). The data were analysed through thematic analysis using NVivo 12 software. Study III is a systematic literature review. The Prisma 2020 statement was followed in the data collection process. Four international databases were consulted: Eric, Scopus, Web of Science, and Academic Search Ultimate, using the search string (programming OR coding OR computational thinking OR robot*) AND (kindergarten OR preschool OR early childhood OR children) AND teaching. The study period extended from January 2010 to May 2022, and the scan yielded 2670 studies. At the end of the process, after inclusion and exclusion criteria were applied, 22 relevant studies were selected for inclusion.

Results: The results of Study I demonstrated agreement among the educators regarding the relevance of critical thinking and reflected on the importance of stimulating critical thinking in ECEC. Educators identified critical thinking with various dispositions and attitudes as the propensity to listen to others' perspectives and the mental habit of being open to and respectful of diverse viewpoints. An association also emerged between supporting critical thinking and children's identity and social development. Educators recognised their role in fostering critical thinking as crucial, and asking open-ended questions was identified as essential to working with and supporting critical thinking.

Study II's results revealed the Norwegian educators' perspectives on the connection between mathematics and higher-order thinking skills, showing that they perceived mathematics as problem-oriented and requiring the identification of solutions. Moreover, the educators were shown to have a positive outlook on the importance of mathematics and mathematics teaching in ECEC. While some educators reflected on their own negative personal experiences with school mathematics, they were nonetheless aware of the importance of not allowing this to influence their daily work with children in ECEC. Overall, the educators' perspectives reflected the notion that daily life offers abundant opportunities to apply mathematics knowledge generally and problem-solving skills specifically.

The results of Study III showed the educators' positive and constructive attitudes towards the use of coding toys and technology in the ECEC context. Of the different scaffolding methods available, dialogic scaffolding appears to be the most widely applied. The results also confirmed the teachers' role as facilitators in the activities with coding toys, whereby they supported children in the coding process rather than simply issuing instructions. Problem-solving skills were the most widely detected and cited output in children's development after coding activities in the selected studies. The use of coding toys supports children in developing indispensable skills that include cognitive and metacognitive skills, such as critical thinking, creative thinking, learning to learn and self-regulation, and social and emotional skills, such as empathy, self-efficacy and collaboration. In ECEC, educators assume the role of human mediators of higher mental functions and thus play a crucial role.

Conclusion: Mathematics, coding toys and educators are suggested as potential mediators of higher-order thinking skills. Mathematics can promote cognitive skills, adding on the educators' aptitude to address the socio-emotional aspects of higher-order thinking. Meanwhile, coding toys may potentially be used as tools to foster both cognitive and socio-emotional skills. Viewed within a theoretical framework informed by the Vygotsky theory of mediated activities, coding toys appear to be a material tool that may become symbolic tools that are subsequently internalised as psychological tools (coding abilities) that—in tandem with mathematics—mediate higher-order thinking skills. However, without educators' interventions, the children may not recognise the symbolic tools and thus may not go on to acquire and internalise the psychological tools. The studies' results underscore the need to identify different mediation techniques and highlight the potential of the pedagogical approach of dialogic scaffolding as a recommended approach to fostering children's development.

List of Studies

Article I

Enrico Pollarolo, Ingunn Størksen, Tuula H. Skarstein & Natalia Kucirkova (2023). Children's critical thinking skills: perceptions of Norwegian early childhood educators, *European Early Childhood Education Research Journal*, 31:2, 259-271. https://doi.org/10.1080/1350293X.2022.2081349

Article II

Pollarolo, E., Skarstein, T. H., Størksen, I. & Kucirkova, N. (2023). Mathematics and higher-order thinking in early childhood education and care (ECEC). *Nordisk barnehageforskning,* 20(2), 70–88. https://doi.org/10.23865/nbf.v20.298

Article III

Pollarolo, E., Papavlasopoulou. S., Granone, F., & Reikerås, E. Play with Coding Toys in Early Childhood Education and Care Teachers' Pedagogical Strategies, Views and Impact on Children's Development. A Systematic Literature Review. *Entertainment Computing* (accepted 1 February 2024, available online 7 February 2024).
https://doi.org/10.1016/j.entcom.2024.100637

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1 Introduction

‘Students who are best prepared for the future are change agents. They can positively impact their surroundings, influence the future, understand others' intentions, actions and feelings, and anticipate the short and long-term consequences of what they do.’ (OECD, 2018, p. 4)

We are currently facing a future in which our children will be required to develop several key skills. The 21st century is the century of knowledge, and in this era of globalisation, this knowledge and information is made increasingly accessible by technological development (Miterianifa et al., 2021).

In this era of rapid changes, we must proceed from simply acquiring information to equipping our children with skills that help them process this information and be ready to face the challenges of this century (Miterianifa et al., 2021; OECD, 2018). The so-called 21st-century skills represent this shift from an education that emphasises the acquisition of basic knowledge and skills to one that emphasises reasoning, problem-solving, and teamwork (Wolff et al., 2020). Those 21st-century skills, which include critical thinking, collaboration, communication, creativity, technology literacy and social-emotional development, are increasingly mentioned in relation to early childhood education, and researchers have recommended their integration into young children’s early learning experiences to help them develop the skills they need not only at school but also in life more generally (Scott, 2017; Wolff et al., 2020).

Higher-order thinking skills represent a central element of these 21st-century skills (Collins, 2014; Conklin, 2011). Such skills include different types of thinking, such as critical, logical, reflective, metacognitive and creative thinking (King et al., 2013), and, among various higher-order thinking definitions, as Brookhart (2010) suggested, they may be sorted into three categories: transfer, critical thinking, and problem-solving.

Children's development and learning are significantly influenced by their educational experiences during their early years. It is thus essential that higher-order thinking skills be fostered in early childhood education and care (ECEC) settings (Lai, 2011). Although higher-order thinking is a popular concept in education from primary school onwards, few studies have focused on higher-order thinking in ECEC.

Moreover, research has also indicated that mathematics is an effective tool for developing higher-order thinking skills in that it trains children to think critically, creatively, logically and systematically to solve problems (Anderson, 1994; Apriani & Rianasari, 2020; Hobri et al., 2018; Richland & Begolli, 2016; Tanujaya et al., 2017). However, this research centres almost entirely on school and higher education contexts.

Another area of potential development of higher-order thinking includes coding activities facilitated by the employment of coding toys. Research indicates that the use of such toys can support those computational thinking skills that are considered part of the 21st-century skill set pertaining to critical thinking and problem-solving (Zaharin et al., 2018), irrespective of age (Çiftci & Bildiren, 2020; Granone & Reikerås, 2021).

Outside the family, educators are crucial in supporting children's development of higher-order thinking skills. Therefore, this thesis investigates the above-mentioned components—mathematics, coding toys and educators—in relation to higher-order thinking through the lens of Vygotsky's theory of mediated activities, which highlights three major classes of mediators: materials tools, psychological tools, and other human beings (Kozulin, 1990, 1998; Vygotsky, 1978, 1986).

The context for Studies I and II is Norwegian early childhood education, while Study III involves an international context through a systematic literature review.

1.1 Structure

This thesis is divided into six main sections. Section 1, the introduction, describes the background to the study. Section 2 presents the definition of higher-order thinking and the theories that underpin the present study. Section 3 details the study's aims and research questions. Section 4 describes the qualitative approach applied and the ethical issues. Section 5 is a summary of the results of each study. Section 6 presents a comprehensive and overarching discussion of the findings in five parts. The first part examines the role of mathematics and coding toys in fostering higher-order thinking skills, beginning with educators' perceptions of higher-order thinking. The second part discusses the role of mediation in fostering children's higher-order thinking skills through Vygotsky's theory of mediated activities. The remaining three parts include a summary with conclusions, implications for practice and recommendations for future research. The thesis ends with the references and the appendices. Appendices include the three Studies and the approval from NSD (now Sikt).

1.2 Background

1.2.1 Higher-order thinking and early childhood

The early years of life are a critical time in children's development and learning (Britto et al., 2017; Daries et al., 2009; Thompson, 2001; Tierney & Nelson III, 2009). A large body of international research has demonstrated the effectiveness of ECEC participation in supporting and improving children's cognitive, linguistic and educational development (Melhuish et al., 2015; Ulferts et al., 2019). Previous research has focused on the importance of children's development within different subjects in social, cognitive, emotional and physical contexts. Various specific learning areas in Norwegian ECEC have been researched extensively, including the nine learning areas mentioned in the Norwegian Framework Plan for Kindergartens (Ministry of Education and Research, 2017), among them language, art, environmental science, mathematics, ethics and society. Internationally, four main topics that are considered to be highly predictive of children's later school success have been studied intensively in relation to ECEC (Duncan et al., 2007): early mathematics, literacy, social development and self-regulation. Despite research efforts in various specific areas, a focus on the mechanisms behind all these subjects appears to be missing. In particular, studies that emphasise the skills that allow children to connect what Anderson and Krathwohl (2001) define as factual, conceptual and procedural knowledge to metacognitive knowledge are lacking. Such skills enable children to use and connect information meaningfully, facilitating their acquisition of new subjects; in other words, this entails the development higher-order thinking skills, which are a central element of 21st-century skills (Collins, 2014; Conklin, 2011; Osborne, 2013; Turiman et al., 2012). Researchers have underlined the significance of learning to think critically from a young age (Salmon, 2008, 2016; Salmon & Lucas, 2011), acknowledging that it establishes a solid foundation for younger children's thinking development. It is thus imperative that the preschool years incorporate strategies and develop appropriate practices to promote higher-order thinking (Aizikovitsh-Udi & Cheng, 2015).

1.2.2 Higher-order thinking and mathematics.

Fostering mathematics skills in ECEC is crucial given that early knowledge and skills in mathematics are strongly predictive of later academic mathematics achievement (Clements et al., 2016; Duncan et al., 2007; Grissmer et al., 2010; Sarama & Clements, 2009). Moreover, research has demonstrated that mathematics can support learning beyond the skills directly required to resolve mathematical problems: in fostering language (Sarama et al., 2012) and reading skills (Duncan et al., 2007), for example. According to Richland and Begolli (2016), mathematical analogical reasoning is a useful tool for fostering students' higher-order thinking. On the other hand research from Apino and Retnawati (2017) shows that the promotion of higher-order thinking skills in mathematics helps students develop abilities such as analysis, evaluation and creativity, which can be useful in solving everyday problems. With respect to future academic careers—in particular, for mathematical students—Tanujaya et al. (2017) indicated that to thrive in learning mathematics, mathematics education students should acquire a high level of higher-order thinking skills. Aizikovitsh-Udi and Amit (2011) and Aizikovitsh and Amit (2010) analysed the possibility of developing critical and creative thinking skills by teaching probability to a group of tenth-grade students. Their findings indicated that the students engaged in critical thinking by studying probability. In particular, they could develop cognitive determination in terms of the ability to express one's opinion with factual support. The researcher's findings represent a step forward in the development of new study programmes and methods that combine critical thinking, creative thinking and mathematics study.

According to Hobri et al. (2018) study, the development of mathematics instructional instruments using contextual teaching and learning (whereby students learn to relate the learning materials to real-world scenarios) significantly affects tenth-grade students' high-order thinking skills. To date, however, the focus has been primarily on the school level up to university, with few studies examining the ECEC context. In this regard, Aizikovitsh-Udi and Cheng (2015) have highlighted the lack of research on higher-order thinking skills in mathematics education and provide examples of activities that can help support students' critical thinking from early childhood through to high school. Accordingly, the authors highly recommend the use of critical thinking instruction in early childhood education. Moreover, as Apriani and Rianasari (2020) have shown, studies focusing on mathematics teachers or pre-service mathematics teachers are required to support them in delivering higher-order thinking-oriented teaching.

1.2.3 Higher-order thinking and coding toys

Coding toys, also defined as programming toys, are electronic, physical agents that can be controlled and programmed by giving logical messages intuitively via direct interaction with the toy without programming on screen. In this thesis, coding toys are approached as a tool to support higher-order thinking in early childhood (Blanchard et al., 2010; Hamilton et al., 2020; Sapounidis & Demetriadis, 2017). Coding toys are examined in greater detail to explore their potential role in integrating higher-order thinking into ECEC practice based on research findings that coding toys support computational thinking (Yang et al., 2020), which is known to be connected to higher-order thinking (Falloon, 2016; Youjun & Xiaomei, 2022; Zaharin et al., 2018).

Computational thinking skills transcend programming and computer science (Wing, 2011) and are considered to be key 21st-century skills (Haseski et al., 2018; Tabesh, 2017). They encompass different skills, including critical thinking, understanding human behaviour (Wing, 2006) and creative thinking, questioning, and problem-solving (Çiftci & Bildiren, 2020; Granone & Reikerås, 2021) and therefore the higher-order thinking skills (Zaharin et al., 2018).

Furthermore, coding toys are typically targeted at young children (Ching et al., 2018). Beginning to use these toys early, at a young age, helps children develop a range of skills, including creativity, mathematical skills, confidence and problem-solving (Mohana et al., 2022). Wing (2006) defined computational thinking as ‘solving problems, designing systems, and understanding human behaviour by drawing on the concepts fundamental to computer science’ (p.33), and contends that it should be taught alongside reading, writing and arithmetic to complete every child’s analytical skill set (Wing, 2006). The development of computational thinking skills in early childhood is fundamental in today’s information-driven society since its systematic problem-solving approach can foster higher-order thinking skills (Ching et al., 2018; Falloon, 2016).

According to Wing (2011), given that computational thinking fosters and improves intellectual skills, it can be transferred to any domain. In line with this, computational thinking and the ability to think systematically can enhance mathematical and scientific expertise (Lye & Koh, 2014), and coding toys may serve as education tool that can support the integration of technology and engineering in early childhood science, technology, engineering and mathematics (STEM) education (Macrides et al., 2021).

1.2.4 Early childhood education context

Norway boasts a high attendance at the *barnehage*, the Norwegian term for ECEC centres or kindergarten for children aged from 1 to 5 years. According to the statistics, 93.4% of all children aged 1–5 attended kindergarten in 2022, and 87.7% of all children aged 1–2 and 97.2% of all children aged 3–5 attended (Statistics Norway, 2022). The Framework Plan for kindergartens is a regulatory framework that provides the content and tasks for kindergartens and guides the kindergarten owner and staff to ensure all children receive high-quality kindergarten provision (Ministry of Education and Research, 2017).

Norway, like other Nordic countries, has a social pedagogy tradition in early childhood education (OECD, 2006) that is founded on a holistic approach to children's learning and well-being (Ministry of Education and Research, 2017) and goes beyond mere preparation for school (OECD, 2006). In this context, outdoor play is regarded as crucial in Norway as a means of promoting children's social development in terms of the opportunity to act, explore and experience in cooperation with others, and research has shown that children in ECEC centres spend, on average, 70% of their time outdoors in summer and 31% in winter (Moser & Martinsen, 2010). The outdoors provides abundant opportunities for learning different subjects in ECEC, including science (Skarstein & Ugelstad, 2020) and mathematics (Lossius & Lundhaug, 2020). In particular, in 2006, with the Framework Plan for Kindergartens' (Ministry of Education and Research, 2006) introduction of a new learning area, 'Quantities, spaces and shapes', which focuses on exploring and discovering mathematics, the importance of working with mathematics in Norwegian ECEC was highlighted.

However, in the Nordic tradition, formative development includes play in addition to learning and care in recognition of the fact that play is a crucial part of all early childhood education activities. Therefore, the pedagogy of play is a widely applied approach that finds considerable resonance in the Norwegian curriculum (Synodi, 2010).

Play-based learning, also called playful learning (Fisher et al., 2011), is essentially learning while at play (Danniels & Pyle, 2018). However, it also invites children to think and make decisions through meaningful, engaging and joyful experiences (Zosh et al., 2017). Playful learning can promote children's academic, socio-emotional and cognitive development (Fisher et al., 2011; Zosh et al., 2017). Play-based learning encompasses two different types of play: free play, which is directed by the children themselves, and guided play, in which the educator is involved in guiding the play at some level (Danniels & Pyle, 2018). In particular, guided play can stimulate creative thinking and problem-solving. The role of the educator as guide is, for example, to introduce a problem to be solved and facilitate children's exploration by asking open-ended questions (Fisher et al., 2013; as cited in Weisberg et al., 2013).

Thus, the role of the educator, as noted above, and the role of play in fostering higher-order thinking are crucial. Play with coding toys in ECEC offers an opportunity for the application of play-based pedagogy in promoting not only basic skills and content knowledge but also those skills that prepare children to meet future challenges (Zosh et al., 2017).

2 Theory

To support the reader in their continued perusal of this thesis, it is necessary to identify and specify what higher-order thinking denotes. Therefore, the first part of this section offers a definition of higher-order thinking skills and the concepts that underpin those skills. The second part will introduce the theory of socio-constructivist learning that has informed this thesis, grounded in the Vygotskian sociocultural perspective that highlights the essential role of mediation to children in the acquisition of higher-order thinking skills.

2.1 Defining higher-order thinking

Although higher-order thinking and its associated skills is a prominent concept in education, it is not easily defined. It may be identified or described in different ways given that it involves various thought processes. The different definitions may depend on the epistemological assumptions that are made: philosophy is rooted in discourse and argumentation, and philosophers are thus more concerned with the use of logical reasoning and perfecting one's thinking to decide what to believe and do. Psychology, by contrast, has developed from a tradition of experimentation and research. Therefore, psychologists focus more on the thinking process and emphasise problem-solving over reflective thinking and logic (Lewis & Smith, 1993). In this respect, Resnick (1987) argues that from a philosophical perspective, when we refer to higher-order thinking, the emphasis is on critical thinking and logical reasoning, while developmental psychologists highlight the significance of metacognition, and cognitive scientists focus on cognitive strategies and heuristics, while educators promote problem-solving.

In an effort to develop a broader term that can encompass the above approaches, Lewis and Smith (1993) elaborated the following definition: 'Higher-order thinking occurs when a person takes new information and information stored in memory and interrelates and/ or rearranges and extends this information to achieve a purpose or find possible answers in perplexing situations' (p. 136).

However, despite researchers' attempts to consider higher-order thinking skills as a unique concept, this thesis explores the notion that higher-order thinking may be approached in different ways, considering it an umbrella term that encompasses different categories of thinking (Miri et al., 2007). This approach made it possible to better identify those skills during interviews with the educators in Studies I and II, depending on the Norwegian Framework Plan for Kindergarten (Ministry of Education and Research, 2017). In so doing, this thesis drew inspiration from Brookhart (2010), who gathered the different definitions of higher-order thinking into three main classes: the group that identify higher-order thinking as critical thinking; the group that identify it as problem-solving; and the group that identify it in terms of transfer. This thesis employs this partition, investigating how these different definitions are approached and implemented in the early educational system, particularly in Norwegian ECEC. Specifically, critical thinking informed the design of Study I, while problem-solving informed Studies II and III.

Although the literature focuses more on problem-solving when the context is education, Norwegian early education, particularly in the Norwegian Framework Plan for Kindergarten (Ministry of Education and Research, 2017), seems to concentrate on critical thinking, as will be explained below. Following the idea of multiple facets to higher-order thinking skills, depending on the epistemological standpoint, this thesis applies a broad approach, examining these important skills for children from different angles.

2.1.1 Higher-order thinking as critical thinking

Multiple definitions of critical thinking have been advanced, but they frequently refer to the same idea of careful thinking directed towards an objective (Conklin, 2011; Hitchcock, 2022). Critical thinking is often regarded as a substitute for the term higher-order thinking or even the practical side of it, since critical thinking refers to deciding what to believe or do (Ennis, 1985). As with Resnick (1987) with higher-order thinking, (Lai (2011), in her literature review, identified different approaches to critical thinking: the philosophical approach, the cognitive psychological approach and the educational approach. The philosophical approach focuses on the critical thinker's traits as opposed to their actions or behaviours. By contrast, the cognitive psychological approach focuses on the opposite. The educational approach relates critical thinking to the top levels of Benjamin Bloom's taxonomy (Bloom et al., 1956) revised by Anderson and Krathwohl (2001), which encompasses to analyse, to evaluate and to create.

Following the cognitive psychologists, Sternberg (1986) also defined critical thinking as the set that included mental processes, strategies, and representations that people put in place when they are required to solve a problem, make decisions, and learn new concepts (Sternberg, 1986).

Study I focuses on critical thinking since, as I shall explain in greater detail in the discussion chapter (6.1), the reference document—namely the Norwegian Framework Plan for Kindergarten (Ministry of Education and Research, 2017)—does not mention the general concept of higher-order thinking skills but emphasises the importance of fostering children's development of critical thinking skills. In Study I, the aim is to explore educators' approaches to critical thinking due to their central role in the mediation processes.

In Study I, in particular, critical thinking is discussed in light of the definition that includes both cognitive skills and dispositions. The ideal critical thinker is characterised by possessing a certain core of cognitive skills (e.g., analysis, interpretation, inference, explanation, evaluation and self-regulations), along with affective dispositions: Facione (1990) as cited by Lai (2011). Some of the most commonly cited thinking dispositions are habits of mind that can include fairness and open-mindedness, respect for others' viewpoints, inquisitiveness, a desire to be well-informed, and the propensity to seek reason and flexibility (Lai, 2011).

2.1.2 Higher-order thinking as problem-solving

Another way of approaching higher-order thinking involves the concept of problem-solving skills. Over time, the definition of problem-solving skills evolved from a simple mechanical and decontextualised set of skills useful for solving problems with a single correct answer to a definition influenced by the cognitive learning theories in which problem-solving involves various cognitive skills and actions characterised by complex mental activities (Foshay & Kirkley, 2003). Study II is founded on this relationship between problem-solving and cognitive skills.

Problem-solving is a cognitive process that is directly aimed at achieving a goal, since it is a process that is internal on the part of the problem solver (cognitive). It involves manipulating knowledge or performing operations in the problem solver's cognitive system (process) and is guided by the problem solver's goal (direct) (Mayer, 2011; Mayer & Wittrock, 2006; Mayer, 1992). Therefore, one of the main characteristics of problem-solving is to be a mode of thinking in which the thinker, through cognitive processes, aims to achieve a goal (Mayer, 2011). This characteristic is emphasised in Study III, wherein problem-solving is one of the cognitive outputs of the implementation of coding activities. A problem solver must be equipped with domain-specific knowledge pertaining to the problem (cognitive skills) and must be capable of selecting the appropriate strategies for applying that knowledge (metacognitive skills).

Motivation also plays an essential role in learning to solve problems. Motivational factors, such as belief and feelings about the problem solver's interest and ability to solve a problem, are central, alongside cognitive and metacognitive skills. Therefore, problem-solver expertise depends on metacognitive and motivational factors as well as purely cognitive ones (Mayer, 1998).

2.1.3 Higher-order thinking as transfer

Among its numerous goals, education aims to promote retention and transfer, two distinct yet equally important competencies. The former concerns the ability to later recall something in the same manner in which it has been presented; the latter represents a meaningful way of learning: while retention requires that the subject remember, transfer implies not only recalling the information but also making sense of it (Anderson & Krathwohl, 2001), as emerged from some educators' responses in Study I.

Transfer skills are involved when knowledge acquired in a situation affects learning or performance in new circumstances (Mayer & Wittrock, 1996). Transfer differs from mere learning, in that the former implies that what we have learned will affect our future performance in another context. By contrast, the latter entails the same effect but in the same task (Salomon & Perkins, 1989). When we can relate that which we have learned to something different beyond what we have been taught to correlate with it, we find ourselves in the sphere of higher-order thinking skills (Brookhart, 2010).

Transfer may take various forms: near transfer, far transfer, or even positive and negative transfer. When the transfer occurs between relatively similar concepts, situations, and contexts, it is defined as near transfer. By contrast, when it occurs between contexts that differ—at least in appearance—it is far transfer (Perkins & Salomon, 1992). Transfer may also be positive or negative. Positive transfer occurs when the knowledge transferred benefits performances in other contexts. It may also be the case that some previous experiences negatively affect the new performance (Mayer & Wittrock, 1996; Perkins & Salomon, 1992). Education focuses on fostering positive transfer; the negative occurs primarily during the first phases when approaching new learning in a new context. Based on this experience, the learner is then able to correct and avoid negative effects in the transfer (Perkins & Salomon, 1992).

Mayer and Wittrock (1996) summarised four historical views of transfer: general transfer of general skills, specific transfer of specific behaviours, specific transfer of general skills, and metacognitive control of general and specific strategies. The first view considers the training of basic mental functions to have a positive general effect that may be transferred in other circumstances (for example, the idea that studying some subjects such as Latin can improve and train children's thinking abilities).

The specific transfer of specific behaviours implies adapting identical behaviours from one task to another (for example, children must learn how to solve a single-column addition before they can solve two two-column additions). Therefore, learning a particular task can help to learn a new task only if the new task contains elements of that particular task.

The specific transfer of general skills applies the same strategy to that described above. However, a general strategy rather than any particular behaviour is transferred from one task to another. In this case, although two tasks may not have identical components, students can learn how to solve new problems after solving one type of problem. This view of transfer proceeds from learning by memorising to learning by understanding.

The fourth view is based on metacognition and summarises, incorporates and completes the previous views. 'In the metacognitive transfer view, successful transfer occurs when the problem solver is able to recognize the requirement of the new problem, select previously learned specific and general skills that apply to the new problem, and monitor their application in solving the new problem' (Mayer & Wittrock, 1996, pp. 50-51). In this type of transfer, problem solvers not only require general and specific knowledge but must also know how to use this knowledge and how to apply it to solve new problems.

The latter definition of transfer conveys the difficulties of defining an approach to higher-order thinking skills without involving any of the other approaches such as problem-solving. Therefore in the following chapter 2.1.4 I will discuss the overlapping among the three definitions of higher-order thinking.

2.1.4 Overlap among the three definitions

The term ‘higher-order thinking’ can thus be approached in different ways. As Brookhart (2010) suggested, the various definitions of higher-order thinking may be categorised under critical thinking, problem-solving, or transfer. Simultaneously, however, those three skill types are grouped under the same umbrella of higher-order thinking skills and contribute to their definition. They are not different, rigid modes of thinking, and they overlap substantially; that is, they are not distinguished by clear boundaries but are dependent on one another.

While some scholars distinguish clearly between the terms ‘critical thinking’ and ‘problem-solving’, problem-solving is commonly subsumed within the term ‘critical thinking’ and vice versa, and the two terms often appear in close association (Granone et al., 2023; Lewis & Smith, 1993). Mayer and Wittrock (2006) consider the terms ‘problem-solving’, ‘thinking’, and ‘reasoning’ to be interchangeable. Specifically, problem-solving is connected to creative and critical thinking because creative thinking is necessary to generate useful ideas for problem-solving, while critical thinking allows us to evaluate ideas that may in turn be useful in solving a problem.

The concepts of transfer and problem-solving may also be regarded as intertwined, given that two types of transfer occur: knowledge transfer, when we use what we have learned in one experience affects the learning in another experience, and problem-solving transfer, whereby the person adapts their ability to solve a given problem to a problem in a different context that requires a solution (Mayer & Wittrock, 1996).

Espousing the idea of multiple facets of higher-order thinking skills intertwined with one another, this thesis implements a broad approach, considering these important skills for children from various angles and epistemological approaches. In particular, as previously mentioned, Study I approaches higher-order thinking in terms of critical thinking on the grounds that the Norwegian Framework Plan for Kindergartens mentions the importance of fostering this higher-order thinking skill on several occasions. While the educators in Study I emphasised transfer as a way of interpreting critical thinking, problem-solving is the higher-order thinking skill investigated in Study II. Study III adopts a broader approach to higher-order thinking skills in terms of different perspectives on children's development after coding activities.

2.2 Social constructivism theory

This thesis is rooted in social constructivism theory and the role that mediation plays in fostering higher-order thinking skills. Meaningful learning is closely connected to constructivist learning, which views learning as knowledge construction, and education encompasses more than the simple presentation, recall or recognition of factual knowledge (Mayer, 2002).

In the context of the constructivist paradigm, while cognitive constructivism, based on Piaget's (1976) work, focuses on the individual's internal processes, Vygotsky's sociocultural theory (Vygotsky, 1978) emphasises the role that social interaction plays in the development of higher-order thinking skills: according to the social constructivist approach, the subject must be involved in social interactions and actively engaged in the learning process.

As soon as they are born into specific sociocultural contexts, children begin to interact with adults and progress from the initial development of lower mental functions, such as associated learning or involuntary attention, to higher functions, such as language acquisition, voluntary attention and problem-solving skills. This development occurs as a result of social contact with more experienced and advanced adults or peers (Doolittle, 1995; Forman & Cazden, 2013). The development proceeds from one stage to another, slightly more advanced stage. Vygotsky defined it 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 a learner engages in problem-solving or skill acquisition, the social context does not intervene exclusively in modelling and imitation. Nonetheless, the involvement of a tutor involves a scaffolding process that enables the child to solve the problem, execute a task or acquire skills that would lie beyond their unassisted efforts (Wood et al., 1976). In this context, scaffolding indicates temporary and dynamic support within the zone of proximal development (Gonulal & Loewen, 2018). This support involves more than an assisted completion of the task, and may result in the development of task competence on the learner’s part at a pace that would far exceed their efforts without assistance (Wood et al., 1976).

This thesis’ argumentation is founded on the research-supported idea, (Lai, 2011) that children can engage in complex thinking at an early stage of life and develop independently of specific stages (Vygotsky, 1978). Following Vygotsky’s theory, this development is the result of social interactions, and educators are thus essential in the process of scaffolding children within the zone of proximal development (ZPD). Children’s learning and thinking are enhanced by responsive educators who are sensitive and capable of scaffolding and extending children’s thinking (Howard et al., 2020).

2.3 Vygotsky’s theory of mediated activity

The child’s interaction with adults, more capable peers and cultural tools is crucial for cognitive change to occur, and through this interdependence of social activity, children can engage higher-order thinking (Hausfather, 1996; Palincsar, 1998; Polly et al., 2017). Cognitive change may occur by means of this collaboration and joint production between a learner and a more experienced learner. The process that underpins this collaboration is mediation, which is the interaction between people and their environment as effected through tools and signals. When cultural signs become internalised, humans acquire the capacity for higher-order thinking (Blake, 2015; Huitt, 2000).

According to Vygotsky, all higher mental processes undertaken by humans are products of mediation, and the concept of mediation has been vigorously emphasised in sociocultural theory (Kozulin, 2018). The activities that elicit higher mental processes are socially meaningful mediated activities for Vygotsky (1978), and the sources of this mediation comprise three major classes: material tools, psychological tools and other human beings (Ghassemzadeh, 2005; Kozulin, 1990, 1998).

Material tools are physical objects that mediate the physical world and can vary from wooden sticks to computers, encompassing everything that human beings have invented in their bid to control nature (Guerrero Nieto, 2007). Material tools are developed to accomplish tasks, are directed towards the objects and processes of nature and exert only indirect influence on human mental processes (Kozulin, 1998).

Psychological tools are symbolic artefacts (signs, symbols, texts, formulae, graphic organisers, etc.) that, having been acquired, become symbolic tools and are subsequently internalised. Once internalised, they become psychological tools and help individuals to master their 'natural' psychological functions of perception, memory, and attention (Kozulin, 1998, 2003). As exemplified by Kozulin (2018), for example, a task that requires the classification of objects or events may be performed using lower-level cognitive functions, such as memorisation, or through a symbolic artefact as a table for organising information. Meanwhile, learning how to use a table to organise information involves acquisition, a stage of the mediation process at which the symbolic artefact becomes a symbolic tool. The second stage implies internalisation—that is, the transformation of the symbolic tool into a psychological tool. In this case, the ability to think about the data in a ‘tabular’ form is the internalised psychological tool that the children can use to analyse, compare and organise other, different types of data. (Figure 1).

Symbolic artefact → (**acquisition**) → Symbolic tool
(e.g., learning how to use a table as an external symbolic tool)
Symbolic Tool → (**internalisation**) →Psychological Tool
(e.g., thinking about data in a ‘tabular’ form)

Figure 1 – Acquisition of the symbolic artefact as a symbolic tool and its transformation into the inner psychological tool (Kozulin, 2018; p. 29).

According to Vygotsky (1981), in the mediation theory (see Kozulin, 1986), psychological tools transform human abilities into superior mental functions. Mathematics and language are examples of such psychological tools. Other examples include mnemonic techniques and decision-making procedures that use material tools, such as dice. Therefore, while material tools are externally oriented, psychological tools are internally oriented (Kozulin, 1986). As Kozulin (2002) emphasised, Vygotsky’s sociocultural theory (Vygotsky, 1978) traces a clear distinction between the individual’s direct experiences with the world due to their direct contact with the stimuli and experiences produced through the mediation of symbolic tools. For Vygotsky (1978), the range of those symbolic tools can vary from the primitive tying of knots or counting fingers to more developed symbolic tools, such as writing, formulae, etc. Children’s cognitive development depends on their success in mastering those symbolic tools in terms of their appropriation and internalisation as psychological tools (Kozulin, 2002).

In this process of appropriation and internalisation, the role of a more experienced subject is essential since the acquisition is not a spontaneous process, and a guided experience is necessary to acquire symbolic relationships. The human aspect of the mediation is particularly salient given that, without a proper mediated activity, symbols may be of no use to children (Kozulin, 2002; Shumway et al., 2021). The child's development occurs by means of the acquisition of symbolic tools that are mediated to the child by adults (Kozulin, 2018).

According to Kozulin (1998), in the context of Vygotsky's mediation theory, the human mediator appears to be a vehicle for symbolic tools. As per Kozulin's analysis, Vygotsky did not attempt to expand the activities of human mediators beyond that role, and this lack was addressed by the mediated learning experience (MLE) theory developed by Feuerstein et al. (1991). According to this theory, the child must realise that the learning objective is not only the realisation of a particular task but also their thinking, reasoning, and cognitive process and 'by constantly focusing on the child's state of attention, problem-solving strategies, mistakes, and insights, the adult infuses the learning situation with a sense of purpose and intentionality. As a result, all three participants in the interactive situation become transformed: the object loses its natural form, becoming an educational construct; the child acquires MLE; and the adult acquires experience as a mediator.' (Kozulin, 1998, p. 66).

As Bussi and Mariotti (2008) also expressed in their theory about semiotic mediation in the mathematics classroom, based on Vygotsky's work, the educator must play on two levels: the cognitive and the metacognitive, 'both fostering the evolution of meanings and guiding pupils to be aware of their mathematical status' (Bussi & Mariotti, 2008, p. 14). For Bussi and Mariotti, the teacher must act as a mediator, using the artefact to mediate mathematical content to the students. Shumway et al. (2021) adapted the Bussi and Mariotti model, employing coding toys as artefacts in the mathematics and programming skills mediation process. In their adaptation, the teacher guides the evolution from artefact signs to mathematical and programming signs (Figure 2).

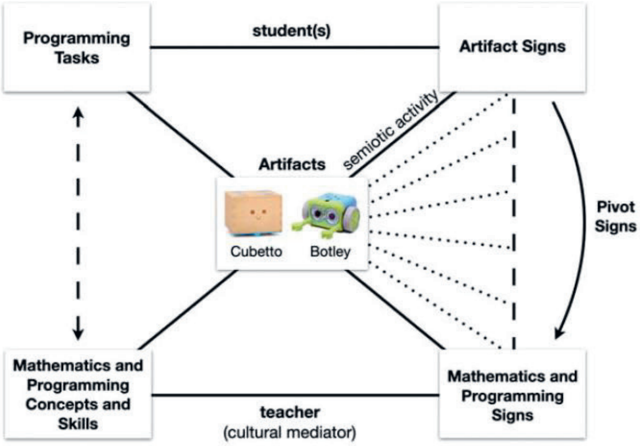

Figure 2 – A diagram of the links among the elements in the theory of artefacts as a tool of semiotic mediation (Shumway et al., 2021, p. 4).

The exploration of more human mediation is thus a priority that should be implemented in terms of deepening the different mediation types and techniques with their corresponding influences on cognitive and learning outcomes (Kozulin, 2002).

The present thesis seeks to address this goal; in particular, it seeks to explore the role that mathematics, coding toys and educators play in terms of mediators and to what extent can help to foster children's higher-order thinking skills by virtue of their potential respective roles as material tools, psychological tools and human beings. In Chapter 6, the empirical results will be discussed in light of mediation theory and the main mediator typologies.

3 Aims and research questions

The aim in this thesis is to contribute to our understanding of higher-order thinking as it occurs in ECEC contexts. In line with sociocultural theory, the intention is to offer a theoretical perspective that links Vygotsky's theory of mediated activities to different approaches to fostering higher-order thinking in ECEC, including mathematics and coding activities.

To this end, I shall explore the domains of mathematics and coding as an area of possible mutual development of children's higher-order thinking skills. In recognition of the key role that they play in fostering those skills, the educators' perspective is prioritised, and therefore, perceptions, approaches and methods are investigated in all three studies.

Accordingly, Study I investigated the ECEC educators' perceptions of critical thinking, while educators' perspectives on mathematics and the connection between mathematics and higher-order thinking skills were explored in Study II. Both Studies I and II involved a Norwegian context, whereas Study III implemented a systematic literature review to explore a broader scenario. While Study I focused explicitly on critical thinking, in Studies II and III, the focus shifted towards mathematics and coding toys with the aim of investigating their role in fostering children's higher-order thinking skills. In Study III, the research questions were posed with the aim of better understanding—in an international context—educators' views, approaches and methods when coding toys are involved. This is because coding toys are considered to be important facilitators for the development of different abilities in children. As such, I was particularly interested in developing a broader comprehension not only of the educators' methodological approaches when using coding toys but also a more precise picture of the types of skills related to higher-order thinking that children can develop through play with coding toys. Figure 3 illustrates the aims of the three studies that comprise the thesis.

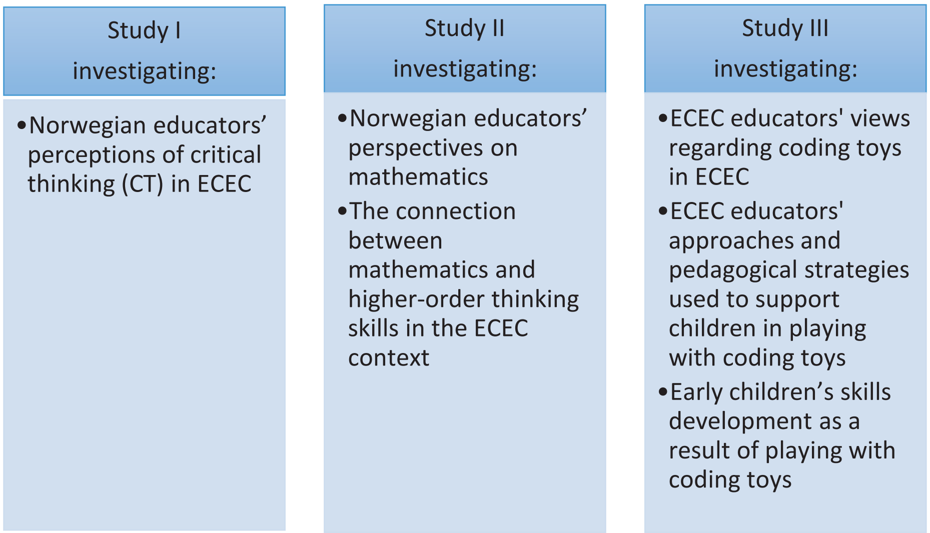

Figure 3 – An overview of the studies and their aims.

Thus, the three studies' guiding research questions were as follows:

Study I

RQ 1. What are Norwegian educators' perceptions concerning critical thinking (CT) in ECEC?

Study II

RQ 2. What are educators' perspectives on mathematics and the connection between mathematics and higher-order thinking skills in the ECEC context?

Study III

RQ 3.1. What are early childhood teachers' views regarding coding toys in ECEC?

RQ 3.2. What pedagogical strategies do early childhood teachers use to support children in playing with coding toys?

RQ 3.3. What detected or expected consequences have been identified with respect to children’s skills development as a result of playing with coding toys?

4 Methods

This section includes a description of the methods applied in the study, the ethical issues (considerations) and the methodological considerations.

4.1 Research design

The present thesis implements a qualitative approach.

Studies I and II explored the perception and understanding of ECEC educators in the Norwegian context.

Study III is a systematic literature review that investigates the relationship between educators, coding toys, and higher-order thinking skills.

4.2 Sample and procedures: Studies I and II

Studies I and II are based on interviews held with ten Norwegian educators from three different kindergartens.

Three different Norwegian ECEC centres were invited to participate in the study. Those centres were among the ECEC centres that had previously collaborated with the University of Stavanger.

The term ‘ECEC centre’ is used in this study to refer to the Norwegian ‘barnehage’, which denotes a premises used for educational and care activities with children aged one to six years prior to compulsory school.

Ten educators agreed to join the study and were interviewed: eight were pedagogical leaders, and two were educators working with children with additional needs. The average participant had 17 years of experience working in ECEC centres, ranging from a minimum of 1.5 years to a maximum of 35 years. Eight educators had 15 years or more of working experience.

First, in preparing the interview guide, the questions were designed to align with the subjects in the Framework Plan (Ministry of Education and Research, 2017). Once the guide was ready, three pilot interviews were conducted with ECEC professional personnel at the University of Stavanger to test the interview questions. These personnel had both academic and practical pedagogical experience as ECEC educators. Therefore, the interview questions were tested, verified and refined based on their feedback.

The interview guide comprised two sections. The first part, which focused on the educators' perceptions of critical thinking as one of the higher-order thinking skills, was used for Study I; the second focused on mathematics and was used for Study II. For practical reasons, the interviews for both studies took place during the same meeting with each educator. Participants received the interview guides several days in advance to allow them to reflect. The interviews were semi-structured, meaning that although the questions were designed cover the topics, the conversation could also vary spontaneously among the participants (Fylan, 2005).

All interviews were conducted in person in a private space at the respective ECEC centres. The interviews lasted from 20 minutes to one hour, depending on the responses, including both the sections for Study I and II. The interviews were audio-recorded and transcribed. A native Norwegian proofread the transcripts to check for any incongruence between the audio recordings and the transcriptions. All participants received a copy of their interview's transcript and approved the content. Quotes translated into English were used in the description of the findings to better explain and clarify the concepts expressed. The research group discussed and verified the quotes.

4.3 Analysis Studies I and II

Thematic analysis was applied to the interview transcripts for Studies I and II in line with Braun and Clarke's assertion that, 'Through focusing on meaning across a data set, thematic analysis allows the researcher to see and make sense of collective or shared meanings and experiences' (Braun & Clarke, 2012, p. 57). The analysis followed the six phases outlined by Braun and Clarke (2006, p. 87), as follows:

1. Familiarising yourself with your data: Transcribing data (if necessary), reading and re-reading the data, noting down initial ideas.

2. Generating initial codes: Coding interesting features of the data in a systematic fashion across the entire data set, collating data relevant to each code.

3. Searching for themes: Collating codes into potential themes, gathering all data relevant to each potential theme.

4. Reviewing themes: Checking if the themes work in relation to the coded extracts (Level 1) and the entire data set (Level 2), generating a thematic 'map' of the analysis.

5. Defining and naming 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.

6. Producing the report: The final opportunity for analysis. Selection of vivid, compelling extract examples, final analysis of selected extracts, relating back of the analysis to the research question and literature, producing a scholarly report of the analysis.

All the above steps were followed. The coding activities were performed using NVivo 12 software, and the data were coded according to four elemental coding methods (Saldaña, 2021): descriptive, in vivo, process and concept coding.

After the codes were first aggregated into themes by one researcher, the other researchers joined the analysis and the final themes were identified through a continuous dialogue.

The data analysis yielded three main themes, each with four or five sub-themes in Study I and three themes with three further sub-themes each in Study II.

The participants' names were anonymised, and educators 1–10 were labelled E1–10 in Study I and Educators 1–10 in Study II.

4.4 Data collection: Study III

Study III is a systematic literature review that followed the PRISMA-2020 statement. In the first step, the following international databases were searched for relevant studies: Eric, Scopus, Web of Science and Academic Search Ultimate. The period examined encompassed January 2010 to May 2022. The search string, including the main key terms, was as follows: (programming OR coding OR computational thinking OR robot*) AND (kindergarten OR preschool OR early childhood OR children) AND teaching. Google Scholar and the snowball method were used to ensure that all major references on the topic were included.

The first step involved the deduplication process, performed using Zotero software. Following deduplication, the total number of records identified was 2670. Those 2670 studies were then evaluated based on the following exclusion and exclusion criteria:

Inclusion criteria

- The study context is ECEC (indicating children aged from one to six years).

- The study includes activities performed by teachers or teachers' views regarding the use of coding toys.
- The study includes activities with coding toys.
- The study is written in English.
- The study is an article.
- The study is published in a peer-reviewed journal or a volume of peer-reviewed conference proceedings.

Exclusion criteria

- The study describes activities that are performed by researchers without including the teachers.
- The study describes activities that are based on technologies other than coding toys (such as apps or tablets).
- The study is a meta-analysis, discourse analysis or (systematic) literature review.
- The study is a book chapter.

Two researchers—the first and third authors—performed the evaluation based on the titles and the abstracts using Rayyan software. Following the screening process, 2420 studies were excluded.

The full texts of the remaining 250 studies were assessed by the first and the second authors; only studies focusing on ECEC teachers' use of robots were retained. Studies that involved children aged above six years (school context), studies relating to humanoid robots and studies that focused exclusively on iPads/tablets were excluded. Articles had to satisfy quality criteria—for example, publication in peer-reviewed venues, the relevance of the topic, definition of a clear research question, appropriate choice of method in accordance with the empirical data, presentation of an exhaustive discussion of the findings in relation to the original research question and good reliability and validity levels.

The Rayyan software guaranteed the independence of the two researchers' evaluations using the option 'blind on', which prevents users from viewing other researchers' assessments.

All researchers were involved in resolving all conflicts that arose during the decision process. The final sample yielded 20 articles. Two further articles were added following a citation search, with the result that 22 relevant studies were ultimately selected for inclusion.

4.5 Analysis Study III

The systematic literature review's synthesis was narrative, with tabular accompaniment, while the analysis was thematic (Grant & Booth, 2009). According to Popay et al. (2006, p. 5), '"narrative synthesis" refers to an approach to the systematic review and synthesis of findings from multiple studies that rely primarily on the use of words and text to summarise and explain the findings of the synthesis'. However, the purpose of narrative synthesis is not merely to list and summarise the included studies' main features; rather, researchers can use this method to compare and contrast studies, explore relationships among the data and provide an overview of knowledge that can be used to inform practice or policy (Lisy & Porritt, 2016).

The collected studies were analysed based on the following areas of focus: the methodology used, the instruments, the areas of interest, the type of activities, the number of participants, the duration of the study, the materials used, the training, the activities, the pedagogical strategies, teachers' views and the children's detected or expected skills.

One researcher performed the analysis, which was reviewed and approved by the other researchers in the team. The data extracted from the 22 studies are included in the tables in Study III's Appendices A, B and C and directly addressed the research questions.

4.6 Ethical considerations

Ethical considerations were presented to and approved by the Norwegian Centre for Research Data (NSD), now Sikt.

For Studies I and II, in addition to the letter inviting them to participate, the participants were also given information about the study, including its purpose, the person responsible for the project and information about the data storage. The voluntary nature of participation was emphasised, and anonymity was guaranteed in all future publications arising from the project. All the educators' rights were specified, including the right to withdraw consent at any time without offering a reason.

The interviews were privately conducted, and only the person specified in the invitation letter had access to the data. No other persons at other institutions had access to the data collected during the study.

4.7 Methodological consideration

While the individual papers report the respective studies' limitations, the main methodological issues are discussed and addressed in this section.

4.7.1 Studies I and II

Interviews are a valuable tool for exploring understanding and perceptions (Clarke & Braun, 2013). This qualitative method was deemed appropriate for Studies I and II.

The question of whether it is feasible to compare and apply the criteria for evaluating quantitative research to qualitative research continues to be the subject of debate (Aspers & Corte, 2019; Clarke & Braun, 2013; Lund, 2005; Shenton, 2004). Lincoln and Guba (1985) defined the criteria for evaluating qualitative research, which, as per Shenton (2004, p. 64), correspond to the criteria employed by quantitative research, as follows:

a) credibility (in preference to internal validity);

b) transferability (in preference to external validity/generalisability);

c) dependability (in preference to reliability);

d) confirmability (in preference to objectivity).

4.7.1.1 Credibility

Lincoln and Guba (1985) identified that credibility is among the most crucial criteria for evaluating trustworthiness. Credibility implies the truthfulness of the findings and the extent to which they reflect the reality of the phenomenon under study (Nassaji, 2020). Various strategies have been developed to ensure the credibility of qualitative data, among which member checks are among the most important for Lincoln and Guba (1985). The accuracy of the data collected is a key element of member checking. As Shenton (2004) observed, these checks may be performed either during or at the end of the data collection. All informants in Studies I and II were asked to read their interview transcripts, and the transcripts were proofread to check for any incongruence between the audio recordings and the transcription.

Member checks also involve sharing the data analysis with the participants and asking them to offer reasons for any patterns that the researcher has observed. Practical issues affecting the informant group in the present study may have impacted the possibility of sharing the results with the participants. However, interpretations of the data in audio records and transcription were peer-reviewed during in-depth discussions among the Studies' authors.

Other strategies were also applied to verify the credibility of the research, as per Lincoln and Guba (1985), cited in Shenton (2004). For example, all participants in Studies I and II were informed about their right to decline participation in the project or to withdraw from the study at any point. This approach can ensure that only genuinely interested participants go on to participate in the interviews. Participants in Studies I and II were also reassured that there were no correct answers to the questions and were encouraged to be free in their answers.

Random participant sampling is another way to ensure credibility since, per Bouma and Atkinson (1995), the use of a random sampling procedure can guarantee that those who are selected are representative of the larger group. No particular purposive sampling techniques were used in Studies I and II apart from the selection of educators in ECEC. The participants were selected depending on the availability of the ECEC centre contacted.

Triangulation may also be used to enhance the credibility of findings and entails various methods, including observation, focus groups and individual interviews (Shenton, 2004). No other methods besides interviews were performed in the present research. Although this could be considered a methodological limitation, triangulation in Studies I and II was guaranteed by the presence of other researchers in discussing the data interpretation (Tracy, 2010).

4.7.1.2 Transferability

Transferability implies that results are to some extent applicable to other situations and populations. After perusing the description of the context in which the research activity was undertaken, the reader decides whether and to what extent the data can be transferred (Shenton, 2004).

The researcher is responsible for facilitating the judgement by providing a thick description, which details the behaviour and experiences and the context to render them more significant to the reader (Korstjens & Moser, 2018). Shenton (2004, p. 70) defined a list of information that should be presented to an outsider, which includes the following:

a) the number of organisations taking part in the study and where they are based;

b) any restrictions in the type of people who contributed data;

c) the number of participants involved in the fieldwork;

d) the data collection methods that were employed;

e) the number and length of the data collection sessions;

f) the time period over which the data was collected.

It is also crucial that the results of a qualitative study be understood in relation to the geographical area in which the fieldwork was performed.

All this information was provided in Studies I and II.

4.7.1.3 Dependability

Dependability corresponds to reliability in quantitative research. According to Bitsch (2005, p. 86), it 'refers to the stability of the findings over time' and 'answers the question whether research results would be the same, were the study replicated with the same or similar participants in a similar context'. Lincoln and Guba (1985), as cited by Shenton (2004), observed a close correlation between credibility and dependability, arguing that a demonstration of the former fosters—to some extent—the existence of the latter. To ensure dependability, it is crucial that all study processes be reported in detail, including the research design and its implementation, the operational details of data gathering and the reflective appraisal of the project. In this way, future research can replicate the work without necessarily obtaining the same results (Shenton, 2004). Studies I and II reported the research design details and how the data were gathered. As a reflexive evaluation of the project, peer debriefing was conducted with the other author, which was similar to the member checks strategy used to enhance credibility (Anney, 2014).

4.7.1.4 Confirmability

Lincoln and Guba (1985, p. 290) define confirmability as 'the degree to which findings are determined by the respondents and conditions of the inquiry and not by the biases, motivations, interests or perspectives of the inquirer'. Confirmability thus denotes the degree to which other researchers can confirm the findings (Anney, 2014; Korstjens & Moser, 2018). It means that we must ensure that the findings reflect the informants' experiences and ideas rather than the researchers' preferences and traits (Shenton, 2004). In other words, confirmability concerns the question of the researcher's prejudices and bias (Bitsch, 2005). Various strategies, including triangulation and audit trails, have been proposed as means of achieving confirmability. An audit trail requires that the researcher keep records of all decisions made with respect to data coding and analysis and rationalising all steps taken (Nassaji, 2020). Although no proper audio trail has been released for Studies I and II, a step-by-step peer review performed during the data analysis supported the attempt to ensure confirmability.

4.7.2 Systematic literature review

The systematic literature search in Study III was performed in accordance with the PRISMA-2020 statement. According to Page et al. (2021), the complete reporting of all PRISMA 2020 items has several potential benefits. It allows readers to determine whether the findings are trustworthy, based on the methods' appropriateness. Furthermore, it simplifies the process of replication and review updates. It also helps policymakers, managers and other decision-makers to formulate appropriate recommendations for practice or policy based on the certainty of the evidence for a given outcome and the implications of findings.

The methods used to conduct a systematic literature review are specified in a review protocol. Researchers should follow a predetermined protocol to minimise the possibility of bias given that, in the absence of a protocol, the research selection or analysis may be influenced by the researcher's expectations (Kitchenham, 2004). Protocols, in addition to guaranteeing against any researcher's arbitrary decisions during the review, allow the reader to verify the presence of selective reporting versus completed reviews (Shamseer et al., 2015). Moreover, if published, protocols can help to prevent duplication while fostering collaboration. Although the protocol in Study III has not been published, it supported the author and the co-authors in keeping track, controlling and eventually collaborating to evaluate and authorise any deviation therefrom.

5 Results

This thesis comprises three articles, the results of which are presented in this section.

5.1 Main findings of Study I

Enrico Pollarolo, Ingunn Størksen, Tuula H. Skarstein & Natalia Kucirkova (2023) Children's critical thinking skills: perceptions of Norwegian early childhood educators, *European Early Childhood Education Research Journal*, 31:2, 259-271,

https://doi.org/10.1080/1350293X.2022.2081349

Study I aimed to provide insight into Norwegian educators' perceptions of critical thinking in early childhood education. The main findings show that the participants had diverse understandings of critical thinking. A strong association was identified between critical thinking and various dispositions and attitudes, such as the propensity to listen to other perspectives and the mental habit of being open to and respectful of diverse viewpoints. All participants agreed as to the importance on critical thinking and reflected on the importance of beginning to stimulate critical thinking development in early childhood education. The results reflect the educators' belief that critical thinking is essential for children's identity and social development. The provision of support for critical thinking lays the foundation for children's social functioning and helps them to construct their self-image. The educators also expressed significant recognition of the centrality of their role as motivators and models in supporting children's critical thinking, acknowledging the importance of focusing on the children and remaining open to their questions and reflections. The practice of asking open-ended questions was identified as an essential key to working with and supporting critical thinking.

5.2 Main findings of Study II

Pollarolo, E., Skarstein, T. H., Størksen, I. & Kucirkova, N. (2023). Mathematics and higher-order thinking in early childhood education and care (ECEC). *Nordisk barnehageforskning,* 20(2), 70–88.

https://doi.org/10.23865/nbf.v20.298

This study examined educators' perspectives on mathematics and the elements of higher-order thinking skills that are foregrounded in the ECEC context when the focus is on mathematics. Findings show the Norwegian educators' open and positive perspective toward the importance of mathematics and mathematics teaching in ECEC. Although some educators reflected on their negative personal experiences with school mathematics, they were aware of the importance of not allowing this to influence their daily work with the children in ECEC. The educators' perspectives reflected their belief that daily life offers abundant opportunities to apply mathematics generally and problem-solving specifically. Moreover, the results revealed the educators' perspectives on the connection between mathematics and higher-order thinking skills, whereby mathematics is regarded as problem-oriented with an emphasis on finding solutions.

5.3 Main findings of Study III

Pollarolo, E., Papavlasopoulou. S., Granone, F., & Reikerås, E. Play with Coding Toys in Early Childhood Education and Care Teachers' Pedagogical Strategies, Views and Impact on Children's Development. A Systematic Literature Review. *Entertainment Computing* (accepted 1 February 2024, available online 7 February 2024).

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This study was a systematic literature review that aimed to identify key aspects and better understand educators' views, methods and approaches to supporting the development of 21st-century skills in children in ECEC during activities with coding toys. The main findings indicate that researchers' interest in the employment of coding toys in early childhood education is increasing. Overall, the results show that teachers have positive and constructive attitudes towards the use of coding toys and technology in the ECEC context. Regarding the teachers' various pedagogical methods and approaches, the results reveal that they employ different scaffolding methods, with dialogic scaffolding the most widely applied. The results also reveal that teachers assume the role of facilitator in activities with coding toys, supporting children in the coding process rather than simply issuing instructions. In the selected studies, among the higher-order thinking skills, problem-solving skills were the most detected and cited output in children's development after coding activities. The use of coding toys allows children to develop indispensable skills, including cognitive and metacognitive skills, such as critical thinking, creative thinking, learning to learn, self-regulation and social and emotional skills, such as empathy, self-efficacy and collaboration.

6 Discussion

Given the critical role that higher-order thinking skills play in children's development and their future lives (Collins, 2014; Conklin, 2011; Osborne, 2013; Turiman et al., 2012), it is essential that the existing approach to those skills in the ECEC context be reinforced (Lai, 2011; Salmon & Lucas, 2011). This thesis aims to contribute to the knowledge of higher-order thinking in ECEC through the lens of Vygotsky's theoretical perspective on mediated activities. In this context, the roles that mathematics, coding toys and educators play in mediating higher-order thinking skills are investigated. To achieve this aim, this thesis first explored the Norwegian ECEC educators' perceptions of critical thinking (Study I), followed by their perception of mathematics and the correlation between this subject and higher-order thinking (Study II), while Study III investigated the coding activities as supporting tools for children's higher-order thinking skills development and the educator's role in a more international context through a systematic literature review. The results are discussed and divided into two main themes: the role that mathematics and coding toys play in fostering higher-order thinking skills, beginning with the educators' perceptions of higher-order thinking (6.1) and the role of mediation in nurturing children's higher-order thinking skills in line with Vygotsky's theory of mediated activities (6.2).

6.1 Higher-order thinking skills: the role of mathematics and coding toys

The first step in this project was to identify the most appropriate way to approach higher-order thinking in the interviews with ECEC educators. As underlined in the theory chapter, higher-order thinking skills have different facets, depending on the approach angle; moreover, their boundaries are not clearly defined, and they can be interchangeable. The first move was to investigate how the Norwegian Framework Plan for

Kindergarten (Ministry of Education and Research, 2017) approaches higher-order thinking skills. While the document contains no direct mention of higher-order thinking, critical thinking is mentioned three times; therefore, higher-order thinking was approached as critical thinking in the interviews. The results indicate that the educators dealing with and attempting to define this concept identified critical thinking as embodying diverse mindsets, such as the propensity to listen to other perspectives, the habit of keeping an open mind with respect to other people's ideas and viewpoints and the propensity to collaborate to find solutions. The analysis in Study I traces these mindsets in the dispositions that Lai (2011) identified in her literature review as one of the two components of critical thinking. Together with cognitive abilities, they represent critical thinking. In her review, Lai (2011) observed this argument on the part of several researchers (Ennis, 1985; Facione, 1990, 2000; Halpern, 1998; Paul & Elder, 1992) and identified a broad consensus on the importance of being equipped with both the ability and the disposition to think critically: 'By this standard, a person who is capable of thinking critically and chooses not to do so is not a critical thinker' (Lai, 2011, p.12). Cognitive abilities or skills—the second main component in the definition of critical thinking—include the ability to engage in cognitive analysis, interpretation inference, evaluation explanation and self-regulation (intended as self-examination and self-correction) (Facione, 2011).

Analysis of the Framework Plan for Kindergarten (Ministry of Education and Research, 2017) reveals why educators are inclined to connect critical thinking to dispositions and attitudes. The Framework Plan mentions the term 'critical thinking' three times. In three sentences, the Ministry of Education and Research (2017) invites early childhood institutions to foster children's development of critical thinking through the employment of interaction, dialogue, play and exploration; in particular, the children should be encouraged to formulate questions, listen to others, reflect and find answers.

The Framework Plan further associates critical thinking with ethical behaviour and the expression of solidarity or ethical judgement. This approach aligns with the holistic social pedagogical approach described in the Norwegian Framework Plan (Wolf, 2021) and more extensively with the Norwegian socio-pedagogical early childhood education tradition (OECD, 2006). The results of Study I confirm this approach to critical thinking, which is more inclined towards disposition and attitude and appears to overlook the cognitive skills.

The results of Study II indicate that half of the educators associated mathematics with being problem-oriented and able to find solutions. This result relates to mathematics learning by virtue of the fact that problem-solving is regarded as essential in mathematics (Wilson et al., 1993) and early childhood mathematics (Clements et al., 2003).

Furthermore, in the latest version of the Norwegian Framework Plan (Ministry of Education and Research, 2017), the concept of problem-solving was introduced in the mathematics chapter for the first time. Problem-solving is presented in the Framework Plan as an ability that must be stimulated and associated with a sense of wonder and curiosity: 'The learning area shall stimulate the children's sense of wonder, curiosity and motivation for problem-solving' (Ministry of Education and Research, 2017, p. 53). Together with numeracy and geometry, problem-solving is among the main goals in mathematics articulated by the Norwegian Framework Plan.

Considering the overall connection between higher-order thinking and mathematics, the analysis suggests that, for educators, supporting higher-order thinking through mathematics in ECEC means acting on the ability to solve problems and, therefore, shifting the focus further towards the mental and cognitive skills, such as analysis and interpretation, that people employ in solving problems (Lai, 2011).

As mentioned in Study II, the educators interviewed about critical thinking in general focused more on attitudes and dispositions; however, when considering a particular context or domain, such as mathematics, they tended to focus on ability rather than disposition and attitude. In this respect, the overall results suggest that mathematics may be considered a domain that completes the approach to higher-order thinking with the cognitive process that is typical of the subject, integrating the social and emotional aspects of higher-order thinking highlighted in Study I. Improved integration of cognitive skills and dispositions in fostering higher-order thinking skills appears increasingly possible and more accessible with mathematics. A further advantage is that problem-solving and logical reasoning facilitate better mathematics learning (Perry & Dockett, 2008; Reikerås, 2008).

Supporting a more cognitive approach in terms of skills and abilities, such as judgement, decision-making and problem-solving may hint at a possible tension with those Norwegian socio-pedagogical traditions. However, the inclusion of the problem-solving concept in the latest revision of the Framework Plan appears to testify that cognitive skills and abilities, such as problem-solving, have attracted increasing attention in recent years. This may indicate that the socio-pedagogical tradition has begun to be influenced by the attention to that side of higher reasoning connected more with cognitive development.

Study III's results highlighted that the use of coding toys in ECEC fosters positive outcomes with respect to children's development across various cognitive and socio-emotional areas. Problem-solving is among the most widely cited cognitive skills developed by children, detected both in the activities and in the educators' opinions (Erdoğmuş, 2020; Hacıoğlu & Suiçmez, 2022; Heikkilä & Mannila, 2018; Kewalramani et al., 2020; Liu et al., 2013; Nam et al., 2019; Otterborn et al., 2019). Collaboration and communication are the two most widely fostered socio-emotional skills in the implementation of coding activities: the children communicate and cooperate and are willing to share their ideas and reasoning, explain to one another and draw conclusions (Bers et al., 2013; Bers et al., 2019; Fridberg & Redfors, 2021; Heikkilä & Mannila, 2018; Kewalramani et al., 2020; Liu & Iversen, 2022; Otterborn et al., 2019; Wang & Wang, 2020). The use of robots can stimulate six key behaviours in children: communication, collaboration, content creation, choice of conduct, creativity and community building (Wang & Wang, 2020). Study III concludes that the use of coding toys allows children to develop essential skills, including cognitive and metacognitive skills such as critical thinking, creative thinking, learning to learn and self-regulation and social and emotional skills such as empathy, self-efficacy and collaboration. Metacognitive skills are essential for selecting appropriate strategies for applying the knowledge acquired through cognitive skills.

While Study II's findings indicate that mathematics plays a key role in supporting cognitive skills, the review in Study III highlights coding toys as tools that offer multiple benefits in terms of fostering and developing children's higher-order thinking skills. Both mathematics and coding activities support these fundamental higher-order thinking skills; mathematics is more supportive for the cognitive aspects, while coding activities are more supportive for both cognitive and socio-emotional skills, for both skills and dispositions and for both abilities and attitudes.

Study III's results confirmed the association between the use of coding toys and the development of computational thinking skills. Computational thinking, with its phases of abstraction, decomposition, algorithmic design, evaluation and generalisation (Selby & Woollard, 2013), is regarded as a problem-solving process (Maharani et al., 2019; Selby & Woollard, 2013; Voskoglou & Buckley, 2012) and is particularly applicable in everyday life in terms of training structured thinking for problem-solving (Andrian & Hikmawan, 2021). Moreover, the results indicate that, after coding activities, problem-solving skills are the most commonly detected and cited output in children's development. Study III's results also indicate a predominance of STEM both in the areas of interest and as output in children's development when coding toys are involved. Coding activities support not only technology and engineering—the two subjects more ostensibly associated with robotics—but also mathematics and science. These subjects require the same skill—the ability to solve problems—which is the common ground with computational thinking (Granone et al., 2023). Coding activities can help children acquire problem-solving abilities and help children also achieve those socio-emotional skills by means of interactions and mediation that occur during the coding activities. Moreover, as the results of the systematic literature review in Study III suggest, the implementation of coding toys may also support and influence mathematics learning (e.g., Palmér, 2017; Shumway et al., 2021).

As a first result, this thesis suggests that the direct approach to the higher-order thinking skills in Norwegian ECEC may be limited to those socio-emotional aspects that characterise the Norwegian socio-pedagogical tradition. In recent years, particularly with the latest revision of the Norwegian Framework Plan (Ministry of Education and Research, 2017), greater attention has been paid to mathematics and problem-solving, which can help highlight the cognitive side of higher-order thinking skills in ECEC. However, a more holistic approach to those skills, both in terms of abilities, dispositions, and cognitive skills, may be required to better support children's higher-order thinking skills development. In this context, the implementation of coding activities using coding toys appears to facilitate this integration, supporting children's socio-emotional and cognitive skills.

Based on these results, the sub-chapter that follows will theoretically discuss the role that mathematics and coding toys play in fostering children's higher-order thinking skills through the lens of the Vygotsky theory of mediation. In this respect, with mathematics and coding toys, we cannot disregard the role of educators as human mediators.

6.2 The role of mediation in fostering children's higher-order thinking skills

This thesis has highlighted the reciprocal and beneficial relationship between mathematics, coding toys and higher-order thinking.

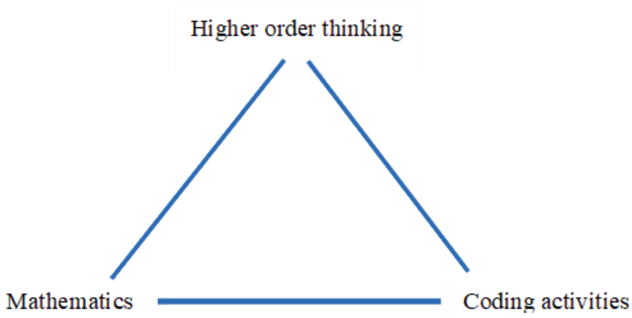

Figure 4 – The reciprocal connection among higher-order thinking, mathematics and coding toys.

In these mutual relationships, the role of mediation is crucial in supporting these skills and in linking them on a theoretical level. According to the Vygotsky theory of mediation, a coding toy may be regarded as a symbolic artefact in all its components: robots, arrows and maps. As Kozulin (2018) asserted, once the child has acquired the symbolic artefact as a symbolic tool, the next step is the internalisation of the symbolic tools as inner psychological tools.

Adapting the example given by Kozulin (2018, p. 28) (see Figure 4) regarding the use and transformation of a table into a psychological tool, in a hypothetical activity with coding toys in which children must move an object from one place to another and must therefore orient themselves and plan a route, coding toys offer a way of performing the task with a higher cognitive function, via the path built through the programming of the coding toys, both in terms of robots and arrows.

Symbolic artefact → (**acquisition**) → Symbolic tool
(learning how to use coding toys as an external symbolic tool)
Symbolic Tool → (**internalisation**) →Psychological Tool
(e.g., thinking about data in a "computational" form)

Figure 5 – Acquisition of coding toys as a symbolic tool and its transformation into an inner psychological tool (Kozulin, 2018; p. 29).

Coding toys, as symbolic artefacts, once acquired by the children, become symbolic tools. In this first phase of the mediation process, the child has learned how to use coding toys as a tool for programming paths. After the second stage of the mediation—internalisation—the coding toy progresses from being an external symbolic tool to an inner psychological one. Thus, children can learn to think algorithmically, formulating and solving problems that are broken down into small steps; they can learn to think computationally, which, as noted above, involves various higher-order thinking skills, such as problem-solving, critical and creative thinking skills (Çiftci & Bildiren, 2020; Falloon, 2016; Granone & Reikerås, 2021; Wing, 2006; Youjun & Xiaomei, 2022).

The use of coding toys facilitates activities such as representing a problem in different modalities, generalisation and classification. These activities support the appropriation and internalisation of psychological tools and, therefore, the development of higher psychological tools, which are connected to and dependent on those tools (Kozulin, 2002). Coding and decoding are also included in Feuerstein and Jensen's (1980) Instrumental Enrichment Program And Psychological Tools—an enrichment program that provides an MLE to students with cognitive deficiencies through instrumental enriching material.

Examination of the definition of transfer skills reveals the connection and similarity between the concept of internalising a psychological tool and the acquisition of the metacognitive transfer ability. Both imply the development of the aptitude to recognise a problem's requirements and select and use strategies already acquired in other situations. Metacognitive transfer is rooted in awareness of one's cognitive processes (Mayer & Wittrock, 1996). According to Kozulin (1998), the cognitive process and children's consciousness of their own thinking in learning situations through a particular task are the primary goals of a mediated interaction.

According to Shumway et al. (2021), coding toys create opportunities for children to engage with mathematics. The authors explored kindergarten students' implementation of mathematics while solving programming tasks. In the activities, the use of artefacts such as coding toys allowed exploration of the links between the artefact and the mediated content, such as mathematics or programming. Therefore, coding toys can also assume the role of psychological tools in supporting and mediating mathematical concepts.

Supposing, however, that the symbolic tool is not internalised and it fails to become a psychological tool. This is the case with mathematics when it is taught in a transcendent manner, whereby the learning is focused exclusively on the context without the mediation of the generalised instrumental function (Kozulin, 2002). When this occurs, mathematics skills are isolated and exert little effect on students' cognitive and problem-solving abilities (Kozulin, 2002; Kozulin & Lurie, 1994).

Even in the presence of a clear symbolic relationship, we cannot assume that children will be able to perceive and easily understand it. As such, we cannot presume that such educational aids are useful in themselves (DeLoache, 1995). Children may not be able to appropriate symbolic systems if they are not properly mediated, and as Kozulin (2002) observed, this is the case with computer-based learning programmes:

‘The computer is potentially a very rich source of psychological tools. However, these tools are not going to be appropriated by children if the interaction between children and the computer remains unmediated’ (Kozulin, 2002, p. 32).

In this context, human mediation is crucial in children’s internalisation of psychological tools, and educators, together with mathematics and coding toys, play a critical role. To investigate this role, this study explored the educators’ views and propensity towards these aspects.

In Studies I and II, the educators expressed positivity regarding critical thinking, mathematics, problem-solving and the correlation between them. The participants agreed on the relevance of critical thinking in Study I and mathematics in Study II. In terms of stimulating critical thinking skills (Study I) and fostering mathematics skills (Study II), the educators were unanimous on the importance of beginning to support those stimuli in early childhood education. This positive approach is essential in ensuring that the educator is consistent and systematic in helping children acquire and develop higher-order thinking skills (Aizikovitsh-Udi & Cheng, 2015) and build confidence in mathematics (Björklund, 2012; Johnston & Bull, 2021). The educator’s positive attitude towards higher-order thinking and mathematics in ECEC is a good precondition for the use of mathematics to develop thinking abilities and skills.

In Study III, which had a broader sample, the results indicate that the educators were predisposed to the introduction of robotics and coding toys in ECEC as a means of supporting children’s cognitive and socio-emotional skills. A positive attitude toward educational technology and a behavioural intention to use it will ensures that preschool educators are more inclined to use it in their activities: the more engaged they are in integrating educational technology into their daily activities, the more likely it is that they will implement it (Rad et al., 2022).

The overall results regarding educators' positivity are an important prerequisite for the opportunity of fostering higher-order thinking skills through the use of mathematics and coding in ECEC. However, according to Kozulin (1998, 2002), the human mediation role has not been sufficiently explored, and mediation techniques and their role in cognitive and learning outcomes in particular should be classified, studied and developed.

Therefore, educators' approaches were investigated in Studies I and III. The findings suggest that, in both cases, the preferred—or, at least, most cited—approach is one that supports children through dialogic interaction, which may be the practice of asking open-ended questions, as in Study I, or the implementation of a dialogic exchange between the educators and the children as in Study III. In Study I, many educators identified the practice of challenging children with open-ended questions as key to working with and supporting critical thinking. Questions are among the most powerful teaching tools (Tofade et al., 2013), and they play a central role in developing higher-order thinking skills (Conklin, 2011). Questions that require high-level thinking, such as open-ended questions, can be designed to support or exercise children in thinking and problem-solving (Siraj et al., 2015) and also can foster their critical thinking skills (Nappi, 2017). To maximise the benefit of open-ended questions, for example, educators must be open to accepting more than one answer to the question; they must be open to the possibility that the child's responses will not correspond to any of the educators' predetermined answers (Siraj-Blatchford & Manni, 2008). Dialogic scaffolding is a pedagogical approach that capitalises on the power of conversation to foster children thinking, learning and problem-solving. Therefore, dialogic exchanges are vital for promoting deep learning, deeper thinking and communication skills in students of all ages (Alexander, 2008). The potential to develop computational thinking skills through the support of social dialogue during tangible programming games has been confirmed in an exploratory study published by Liu and Iversen (2022). The early childhood context, in which play assumes a central role, is a perfect arena, given that play creates good opportunities for dialogic interactions (Salminen et al., 2021).

Regarding the educators' approach to higher-order thinking, this thesis also investigates how this approach influences their professional identities. Specifically, in Study I, the focus is on the educators' ideas regarding their own position, while Study III focuses more on the actual roles that the educators play. The studies' common ground is the centrality of the educators' role not only in transmitting information but also in facilitating learning (Gokhale, 1995; Hanno et al., 2021), which is an important aspect to bear in mind when we address the concept of human mediation. As in Study I, in which the educators emphasised the importance of not providing answers immediately but supporting children in finding them, in Study III, during the activities with coding toys, educators supported children in the coding process while avoiding simply issuing instructions. In Study I, the educators underline the importance of remaining open to children's questions and reflections and involving them in the process of supporting their learning, corroborating the assertion that to help children to become active thinkers, educators must actively involve them in the thinking process (Conklin, 2011; Pithers & Soden, 2000). Similarly, the mediation role that educators were shown to provide in Study II enhances children's propensity for learning (Howie, 2019). Educators' roles as supporting adults require teaching beyond formal mathematics, which means moving from traditional teaching approaches—in which the educator is responsible for showing and explaining—to a function of open guidance in helping children to develop their own thinking (Anghileri, 2006). Educators have the potential to make a significant impact through their role in the mediation process. According to Kozulin (1998), the adult imbues the learning situation with a sense of intention and purpose by continuously mediating the child's attention, problem-solving strategies, mistakes and insights. In this way, the object, the child and the educators become transformed during the interaction: the object becomes an educational construct, and the child acquires MLE while the educator gains experience as a mediator.

Moreover, Study III's results reveal that educators help children to develop computational thinking skills by being supportive and mediating. While in Study I, the educators emphasised the importance of the children failing and trying again, in Study III, the subject programming allows the children to be free to make mistakes so that they may learn from them. Both Studies I and III emphasised supporting children by remaining at a distance and not only avoiding giving them answers too soon but also avoiding correcting them too soon. Educators can mediate the students' learning by coaching, facilitating and scaffolding (Niu & Niemi, 2019).

6.3 Conclusion

Higher-order thinking skills are essential for children (Conklin, 2011; Lai, 2011; Salmon & Lucas, 2011), and this thesis aims to enhance our understanding and knowledge of these skills in the ECEC context.

In particular, this thesis investigated the potential of mathematics and coding activities as supportive domains and, following the Vygotsky theory of mediated activities (Vygotsky, 1978, 1986), their role—along with that of the educators—as mediators in children's higher-order thinking skills development.

Higher-order thinking may be perceived differently and embrace different categories of thinking (Miri et al., 2007); however, in Study I, when the focus was on critical thinking in general, the educators emphasised those dispositions and attitudes that constitute—together with cognitive abilities—the general concept of critical thinking (Lai, 2011). However, when the focus of the interviews shifted to mathematics (Study II), cognitive abilities, through problem-solving, were highlighted more. Therefore, although Study I's results appear to support the aspects of higher-order thinking connected with the Norwegian socio-pedagogical tradition, such as dispositions and attitudes, to a greater extent, Study II's findings and the latest version of the Framework Plan suggest a reinforcement for the cognitive side through mathematics.

Study III's results revealed that the implementation coding activities through unplugged or plugged activities with coding toys affects children's problem-solving skills. Moreover, Study III also highlighted the development of those socio-emotional skills, such as communication, collaboration, and community building, which may be redirected towards the abilities and dispositions mentioned by Lai (2011) and discussed in Study I. Therefore, Study III's findings and the overall findings of this thesis suggest that, similar to mathematics, coding activities can serve as supporting domains for fostering higher-order thinking skills. In particular, while mathematics can promote the cognitive side, coding activities can promote both the cognitive and the socio-emotional aspects.

According to the Vygotsky theory of mediated activities (Vygotsky, 1978), the mediators are defined according to three major classes: material tools, psychological tools and human beings (Kozulin, 1998). In line with this theoretical perspective, this thesis highlights the role that the coding toys play as material tools and, once internalised, as psychological tools that support the acquisition of those higher-order thinking skills. Mathematics is also a psychological tool that is intended to support those skills. However, all these mediators are useless without the support of the third mediator type—the human being. From both a more restricted context, as in Study I, and a broader setting, as in Study III, the findings revealed the educator's mediating role in supporting children as they progress through the ZPD (Vygotsky, 1978). They also emphasised the role of the educator as a facilitator in maintaining a distance from the children, not giving answers immediately but rather supporting the children in finding the answers and remaining open to their questions.

As underlined by Kozulin (1998, 2002), the human being—the educator—is not merely a carrier of signs, symbols and meanings. However, human mediation requires further in-depth investigation—in particular, the different mediation techniques and their influence on the cognitive outcomes. The results of the three studies showed the pedagogical approach of dialogic scaffolding as it is embedded in this context of mediation.

This thesis found that dialogic scaffolding is a widely recommended (Study I) and implemented (Study III) approach to fostering children's development. Asking open-ended questions is a pedagogical approach that is particularly supportive of the thinking process (Siraj et al., 2015).

Dialogic scaffolding is a pedagogical approach that provides children with opportunities to engage in deep thinking and learning (Alexander, 2008).

The present thesis aimed to advance our understanding of higher-order thinking skills in early childhood education—in particular, providing insight and perspectives on how these skills might best be nurtured. This thesis also aimed to provide a theoretical contribution aligned with Vygotsky's theory of mediated activities, framing mathematics, coding toys and educators as mediators in fostering young children's higher-order thinking skills.

6.4 Implications for practice

This thesis contributes to research in terms of the approach to higher-order thinking skills in the ECEC context. Research has emphasised that the ability to think critically implies being equipped with both cognitive skills and dispositions, which are considered to be separate entities (Lai, 2011; Lai & Viering, 2012). The present study's findings appear to indicate that, due to the socio-pedagogical approach of this context, the focus in ECEC contexts is more on the dispositions than on the abilities. In this respect, educators' consciousness of their purpose in teaching mathematics can help foster cognitive skills. Work with coding toys also offers a means of supporting both abilities and dispositions and is well situated within the play-based ECEC context. Educators should maintain awareness of the ultimate goal of supporting higher-order thinking skills when working with mathematics and coding toys.

A practical implication of the studies concerns the approach to ECEC mathematics in a more problem-solving-oriented way (Lopes et al., 2017) that supports the children's higher-order thinking skills. This thesis also supports and prompts the employment of coding activities in ECEC due to the support that these activities offer to higher-order thinking, in addition to the other various positive aspects. In this respect, this approach to mathematics should be taught and emphasised in early childhood teacher education (ECTE). Moreover, ECTE students' professional digital competence should also be enhanced, cohering in particular around enriching and supporting children's play with coding activities. In the Norwegian context, in particular, although the Framework Plan for Kindergarten (Ministry of Education and Research, 2017) encourages digital practices through the use of digital tools that support children's learning process, research suggests that Norwegian ECEC educators must improve their professional digital competence to effectively support children's play with technology (Fagerholt et al., 2019; Fjørtoft et al., 2019).

As human mediators, educators play an essential role. In line with Vygotsky's theory of mediated activities, the possibility that psychological tools, such as coding toys, would be internalised as psychological tools without the intervention of human mediators is low. According to (Kozulin, 2002), it is necessary to expand the existing knowledge of different mediation techniques, and this thesis underscores the importance of dialogic practices. In the context of mathematical or coding activities, therefore, the ECTE should include the correct application of dialogic pedagogical practices to foster higher-order thinking skills.

6.5 Limitations and implications for future research

The ambition of this thesis is to raise awareness of the need to investigate and develop approaches to supporting higher-order thinking skills in ECEC.

In line with this aim, considering the results obtained in this thesis and the limitations of the individual studies, several suggestions for future research may be offered here.

While Study III analysed an international context by means of a systematic literature review, Studies I and II included a limited number of educators. It would be interesting to increase the number of educators involved in a survey that encompasses educators from a larger area. An investigation of an education environment other than the Norwegian model—as was indeed planned for this thesis prior to the COVID-19 pandemic—might also facilitate valuable and revealing comparison.

The COVID-19 pandemic affected research in many areas (e.g., Kucirkova et al., 2020), particularly early childhood education, making field research difficult or even impossible. Now that it is possible to return the field, other study types (in terms of methodology) may be undertaken. Future research should observe the actual practice in the early childhood context when fostering children's higher-order thinking skills; triangulation should be applied to guarantee even higher credibility of the qualitative research.

With the educators as the subject, particularly in Studies I and II, and with no documentation of their actual practice, it was not possible to determine how their perspectives are reflected in their activities with the children. A considerable step forward would involve a shift in focus from the educator to the children: a longitudinal study comparing higher-order thinking skills in children in relation to the implementation of specific mathematical or coding activities would be of interest. In this regard, specific pedagogical practices based on dialogic scaffolding may be defined, implemented and verified.

Finally, the approaches to higher-order thinking in terms of critical thinking and problem-solving were prioritised in this thesis. Research that also addresses the components of higher-order thinking that are closer to the concept of transfer may be preferable in terms of attaining a more comprehensive overview of higher-order thinking skills from multiple perspectives.

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Appendices

Appendix 1 – Study I

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Children's critical thinking skills: perceptions of Norwegian early childhood educators

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ABSTRACT
The significance of learning to think critically from a young age is well documented. Early childhood educators play an essential role in children's critical skills development. Therefore, it is crucial to understand their perceptions of this concept. This qualitative study explored Norwegian early childhood educators' perceptions of critical thinking (CT). Ten educators representing three different kindergartens were interviewed. Thematic analyses revealed that the educators had many different understandings of CT; all agreed on the importance of CT for children's development and identified their role as essential in supporting and stimulating CT among children. They described CT more in relation to a child's dispositions and attitudes than cognitive skills and connected it mainly with social and physical aspects. Overall, this study contributes to raising awareness of the importance of supporting educators' knowledge about the CT concept and pedagogical approaches to enhancing CT in children.

KEYWORDS
Critical thinking; higher-order thinking; kindergarten; Norwegian early childhood educators; thematic analysis

Introduction

The importance of fostering and developing critical thinking (CT) in children from a young age (Lai 2011) has been widely discussed and endorsed in scholarship (Facione 2011; Lipman 1991). Education policy often highlights CT skills as an essential component of twenty-first-century skills – the set of skills needed to solve the challenges of a rapidly changing world and an unpredictable future (Wolff, Skarstein, and Skarstein 2020). CT competency is also one of UNESCO's key competencies in Education for Sustainable Development (Rieckmann 2018). Aligned with this vision is the 'Sustained Shared Thinking and Emotional Well-being' scale. This recognised quality assessment tool for early childhood education and care (ECEC) devotes part of the evaluation to children's higher-order thinking skills' support (Siraj, Kingston, and Melhuish 2015).

The centrality of the educator's role in enhancing and facilitating the development of CT is acknowledged (Pithers and Soden 2000). However, little is known about educators'

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own perceptions of children's CT more broadly and in Norwegian ECEC specifically. Despite extensive research on CT in education in general, few studies are concerned exclusively with children's CT in ECEC, and empirical research on CT in Norwegian ECEC has hitherto been minimal. The present study aimed to address this gap by exploring the Norwegian early childhood educators' perceptions of children's CT.

Definition of key terms

Building on previous definitions in the literature, the present article follows the definition of CT as a higher-order thinking skill involving both cognitive skills and dispositions (Facione et al. 1995; Lai 2011). According to Conklin (2011), higher-order thinking skills incorporate CT and creative thinking. CT is characterised by careful analysis and judgement (Conklin 2011). Moreover, CT has been defined as 'reflective and reasonable thinking that is focused on deciding what to believe or do' (Ennis 1985, 45) and can be regarded as the practical dimension of higher-order thinking (Ennis 1985).

Theoretical framework

The present study follows Vygotsky (1978) sociocultural learning theory, focusing on the role of social interaction in developing higher-order thinking skills (Allman 2020). For Vygotsky, higher mental functions originate in social activity, mediated by tools and signs (Hausfather 1996). When cultural signs become internalised, humans acquire the capacity for higher-order thinking (Huitt 2000). In Vygotsky's view of cognitive development, interaction between adults and children during joint production is indispensable for children's cognitive development. Thus, children engage in higher-order thinking through interaction and social activity (Hausfather 1996); in the ECEC context, educators play a crucial role in these interactions and activities with children.

Study background

Critical thinking requires that the individual have a certain core set of cognitive skills (e.g. analysis, interpretations, inference, explanation, evaluations and self-regulations) along with affective dispositions (Facione 1990). Among the most commonly cited thinking dispositions are habits of mind that can include fair- and open-mindedness, respect for others' viewpoints, inquisitiveness, flexibility, the desire to be well informed and the propensity to seek reason, (Lai 2011). Therefore, according to Facione (2011), the ideal critical thinker is characterised by both cognitive skills and these attitudes and dispositions, which may be regarded as their general approach to life. By developing CT skills and fostering these dispositions, it is possible to educate strong critical thinkers (Facione 2011) and lay the foundation for critical literacy's goal of recognising inequalities and injustices in order to move toward transformative action and social justice (Mulcahy 2008), which forms the basis of a rational and democratic society.

In addition to this wider societal need, there is a pragmatic need to understand the CT concept in Norway, given that it is featured in the Norwegian kindergarten curriculum (Ministry of Education and Research 2017). Although no full definition is provided, The Framework Plan includes three mentions of CT in relation to existential, ethical, and philosophical questions:

(1) 'Kindergartens shall foster the children's ability to think critically, act ethically and show solidarity' (10);
(2) 'Kindergartens shall use interaction, dialogue, play, and exploration to help the children develop critical thinking, ethical judgment and an ability to put up resistance and take action to effect change' (21); and
(3) 'By talking about and wondering at existential, ethical and philosophical questions, the children shall be enabled to formulate questions, listen to others, reflect and find answers. This way, kindergartens shall help steer the children towards critical thinking and sound judgement.' (54) (Ministry of Education and Research 2017).

Our study aims to provide insight into these concepts from kindergarten teachers' perspectives.

CT research has hitherto focused on older children. A Canadian study examined educators' understanding of CT and higher-order thinking from kindergarten to grade 9 and found that the educators regarded CT as an essential skill but also showed a limited understanding of the term (Schulz and FitzPatrick 2016). Another study found that CT development in children aged 4–12 years occurred through a process of fading and appropriation/transformation that can be associated with 'scaffolding' (Daniel and Gagnon 2011). CT has also been linked with the Reggio Emilia approach (Fernández-Santín and Feliu-Torruella 2020). In the Norwegian context, several studies have focused on how to develop CT at school level, (e.g. Børhaug 2014; Elm Fristorp and Roos 2014; Wagner 2019). To the best of our knowledge, only one Norwegian study has addressed CT in kindergarten (Hognestad 2015). That study highlighted the importance of children's active participation in CT and the social practice of thinking.

Recognising the importance of being able to think critically from a young age, as underlined in the literature and in curriculum materials, and given the lack of research on CT in ECEC, our study set out to address the following research question:

What are Norwegian educators' perceptions concerning critical thinking (CT) in ECEC?

Method

Participants

The invitation to participate in the study was sent to three ECEC centres that had previously collaborated with the University of Stavanger. All educators in these centres, who worked with children aged between 4 and 6, were given information about the study. Informed consent to participate in a semi-structured interview was obtained from the educators. In particular, they were assured that the material would be anonymised in all publications relating to the project and that the data would be treated with a high level of confidentiality. Ten educators from three centres responded positively. Eight were pedagogical leaders, and two were ECEC educators working with children with special needs. The participants had worked in ECEC centres for an average of 17 years (minimum 1.5 years; maximum 35 years). Ethical considerations were presented to and approved by the Norwegian Center for Research Data (NSD).

Study procedure

The interview questions were developed and tested through three pilot interviews with ECEC professionals working at the University of Stavanger, all of whom had experience as ECEC educators. The interview questions were adjusted and refined based on their feedback (Appendix A).

To give the ten participants an opportunity to reflect on the interview questions in advance, the questions were sent to them several days in advance of the interviews. The first half of the interview focused on educators' perceptions of CT, and the second half focused on the role of mathematics as a stimulus for children's critical thinking skills. The questions were designed to align with the themes set out in the Framework Plan (Ministry of Education and Research 2017). Owing to the volume of data collected, this article focuses on educators' understanding, approach and perceptions about CT, leaving the theme of mathematics for a future article.

Interviews

The interviews were carried out in person at ECEC centres and lasted 30 min on average, from 20 min up to one hour, depending on the responses. The interviews were audio-recorded and transcribed. The transcripts were proofread to check for any incongruence between the audio recordings and the transcriptions. Participating educators were presented with their interviews in transcribed form to verify that the content was as intended.

Analysis

The interview transcriptions were subjected to thematic analysis (Braun and Clarke 2012) using NVivo 12. The first step of the analysis involved familiarisation with the data, which had already begun during the transcription phase. After the transcripts were validated, notes were taken during multiple readings. Finally, the data were systematically analysed, beginning with data coding. While an inductive approach was generally applied, it is worth emphasising that it is impossible to be purely inductive; researchers always bring their own notions to data analyses to some extent (Braun and Clarke 2012).

The data were coded according to four elemental coding methods (Saldaña 2021): descriptive, in vivo, process, and concept coding. These elemental methods were effective in assigning labels to the data. They were found to be appropriate for identifying concepts and ascribing meaning to the data. Initially, around 140 codes were identified. After the first author conducted the initial analyses, two more authors joined the analysis process. Following several consultations between the researchers during the process of defining and reviewing the themes, the final themes were identified.

Quotations from the transcripts were selected as illustrative examples for each theme. The quotations have been translated from Norwegian to English with considerable effort to preserve the participants' original meanings as far as possible. At times, however, it was necessary sentence structure needed to be altered for readability. The ellipses in parentheses represent parts of the transcriptions that were added for enhanced understanding of the meaning. The participants' names were anonymised, and educators 1–10 were labelled E1–10 in the presented results.

Findings

The data analysis resulted in three main themes, each with four or five sub-themes, as detailed in Figure 1.

- 'CT is so many different things'. Diverse definitions of CT
- 'I think it means everything'. The importance of CT
- 'Awareness of our role is very important'. Educators' role

'CT is so many different things'. Diverse definitions of CT

Participants had diverse understandings of CT, as illustrated by the following quotes. Several educators identified and connected CT with the propensity to listen to other perspectives. For example, E6 explained, '*(CT is) about seeing different perspectives or having different perspectives (...) so they (children) understand that others have a different point of view to theirs*'. Educators emphasised that CT is closely related to the habit of being open to other people's ideas and mindsets. E10 said, '*(CT means being) allowed to be myself and be confident in oneself, but at the same time provide room for others to be themselves.*'

Several educators have reported that CT is also based on the concept of 'wondering together.' The Norwegian word 'wonder' encompasses a deep meaning connected to the ability to be open, the aptitude to be surprised and disposed to reflect and ask oneself about things and marvel at something. As E1 said, '*Every time we challenge children, talk with them, wonder together, it facilitates CT.*' Educators perceive CT as the ability to reflect and wonder together and to learn to think for oneself and wonder what the answer to a question might be.

Participants often mentioned the idea of challenging children with open-ended questions. E7 said, '*It is good if they can wonder about the things we do, we ask them wondering questions, ... , Why do we do this?*' while E9 indicated, '*It is to wonder with the children, to reason forward to something together, with open-ended questions.*'

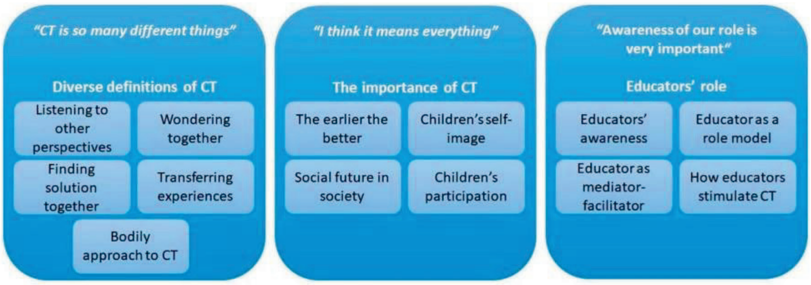

Figure 1. Themes and sub-themes established during the analysis of the semi-structured interviews.

Several educators also believed that the attitude of being respectful of others' ideas and perspectives helps children develop the ability to work together to find solutions. Thus, the educators perceived a connection between CT and the ability to apply different approaches to find solutions together. E1 reflected on this idea: '*If we cooperate, we should consider our approach. What benefits you, what benefits me and us as a team?*' E5 expressed that CT '*is to teach them there is no single answer, but many ways to arrive at the same conclusion.*'

While identifying CT skills with problem-solving abilities, E5 also indicated a link between the development of CT and the importance of supporting children in developing their ability to transfer what they have learned to new experiences: '*What they learn in one setting, they can apply in a new setting.*' E6 emphasised the value of CT in the development of new transferable skills and their application – for example, by using building techniques acquired from the sandbox to new constructions with Lego. For E8, thinking critically means analysing and interpreting personal experiences: '*When a person thinks critically, they analyse and interpret experiences of episodes that they have experienced.*'

The findings suggest that some educators also identified a physical and experiential approach to CT, disconnecting it from an abstract idea. Referring to very young children, E3 said,

> I think all kinds of learning for very young children happen through the body; they learn with their body, they are very physical. So, I think that CT is very experimental, very physical, and not so abstract. (…) they must grasp, touch, grasp to comprehend.

In line with this idea, educators identified embodied learning as important in the development of CT: '*When children are allowed to experience the world through their body and risky play … there is a lot of CT in that*' (E4). E6 said, '*To discover that the knowledge or learning you are confident in is embodied; it has become a part of the working memory, and then we build on this.*'

'I think it means everything'. The importance of CT

The participants all agreed on the relevance of CT and reflected on the importance of beginning to stimulate CT development in early childhood education. As E8 observed, '*Actually, the first thing I kind of thought was the earlier, the better*'. E2 connected this need with future education: '*It will be a very useful skill for children to bring with them as they start school, (…) therefore it is important that we in kindergarten start already now*'.

Educators expressed that CT is essential for children's identity and social development. Educators believe that supporting CT lays the foundation for children's social functioning and contributes to society itself. They noted that supporting children's CT helped them in constructing their self-image. E9 explained that it is important for children's self-image '*that they dare to say their opinion and stand for it*'. The educators believed that developing the ability to think critically imbues children with greater confidence in revealing their authentic selves and to have the courage to stand for something they believe in. As E4 also observed, '*I think it certainly plays a big role, (…), that they are robust, they dare to show who they are, that they dare to stand for something they mean*'. In this context, educators believe that children must be taken seriously and encouraged to express their opinions.

In educators' experience, CT is thus relevant for children's future social development. E1 said, '*I also think that in societies out there we have more and more use for critical thinking. (…) I think it's very important because they are citizens going out into the world.*' The development of CT skills in ECEC '*helps them later in life when they have to learn to be independent, discuss with others, and find solutions to things that happen in life*' (E7). For the educators, CT skills are abilities that children will carry with them throughout their lives: '*to take it with you further in life, in school, in society, … to contribute to society*' (E5).

As mentioned in relation to the previous theme, the educators believe that awareness of their own thoughts and values helps children to understand that other children and adults may have opinions that differ from theirs. Thus, CT skills develop thanks to those abilities of cooperation that are indispensable when we encounter others' points of view: '*It's about being aware of one's own thoughts and values actually, because you also meet other people*' (E6). E1 said, '*We have a problem, (…), and then we have to help each other to help solve this in different ways*'.

In this context, the findings reveal that the educators identified conflict situations as a key arena for working with and developing CT skills: '*We talk to both parties, they are allowed to tell their version, and we ask more open-ended questions, how they think the other child is feeling*' (E4). E8 further observed,

> They disagree on things, so I think it's so important that we intervene, and we emphasise that we tell both sides of the story … we do not just say «now you have to stop» and then they can go out to play … we explain to the kids (…), and then they learn, looking a little bit at both sides of the issue.

Several of the present study's participants also expressed that building and stimulating CT in children means involving them in decision-making processes and encouraging their participation: '*They are allowed to be in the process, to be involved and decide, and so you ask them "What do you think? What do you want?"*' (E8). E10, for example, stated, '*Not having a very tight programme, I think is important … being able to have enough time through everyday life and take the children with you, and to let them choose, maybe through free play.*'

'Awareness of our role is very important'. Educator's role

Educators identify their role as essential when it comes to supporting and stimulating CT among children. First, educators acknowledge that they must be aware of the importance of focusing on the children and remaining open to their questions and reflections. Educators described the importance of their awareness and of being conscious of the need to '*be vigilant about what concerns children, it is most important, all the time. Not necessarily to sit with them and teach, but that you are, in a way, awake to questions*' (E2). Many of the educators emphasised the importance of being open to questions from children as well as open to their reflections and experiences. Again, E2 noted, '*We are conscious of being open to those questions and of getting them to reflect on themselves, to arrive at common and possible answers.*' Educators reported that it was important not to provide answers right away but to support the children in finding them. E4 said, '*I think it is very important that we are open to what the children convey, that we do not* *give them an answer right away but that we help them find a solution. We must ask them the open-ended questions*'. At the same time, educators must '*be present, to be where the children are, (…) when they show interest, to create wonder and curiosity*' (E5), not only physically but also in terms of awareness of the children's interests. The teacher must express their interest and take the children seriously: '*Take children seriously, be interested, be accommodating, show initiative, listen, we are very, very, present*' (E4).

In the process of identifying themselves as facilitators, educators also reported the necessity of following and supporting children's interests. In doing so, educators recognised their role as motivators and models and essential in supporting children's CT. E1 said, '*Awareness of our role is very important.*' E3 had a similar view: '*We adults become very important role models.*'

Many educators identified the practice of asking open-ended questions as key to working with and supporting CT: '*I think that when we ask them such open-ended questions, they get to think critically themselves.*' (E4) Asking open-ended questions in everyday situations is among the most frequently suggested approaches to stimulate CT. E1 summarised as follows:

> I think that there are situations that we experience in kindergarten during the whole day. There are probably a hundred different situations that we experience implicitly. Every time we challenge children, talk to them, wonder at the same thing, it facilitates critical thinking.

Discussion

Our results verify that the participants identified CT as encompassing various dispositions and attitudes (e.g. the propensity to listen to other perspectives) and the mental habit of being open to and respectful of diverse viewpoints. According to the literature review presented by Lai (2011, 2), dispositions and attitudes, such as 'open- and fair-mindedness, inquisitiveness, flexibility, a propensity to seek reason, a desire to be well informed, and a respect for and willingness to entertain diverse viewpoints' together with cognitive skills constitute CT. In this respect, the connection between CT and the ability to wonder formulated by educators is also consistent with the participants' ideas of CT dispositions and attitudes. The development of an inquisitive approach in children, stimulating their curiosity and sense of wonder, is central to the Framework Plan (Ministry of Education and Research 2017). Educators recognised these important aspects of CT as essential dispositions, and these dispositions have also been acknowledged in research as important to the ideal critical thinker (Facione 1990, 2011; Facione et al. 1995). However, research defines the ideal critical thinker as characterised by these dispositions and a set of cognitive skills that constitute the core skills for CT. These skills include the ability to engage in cognitive analysis, interpretation inference, evaluation explanation and self-regulation (intended as self-examination and self-correction) (Facione 1990, 2011; Facione et al. 1995). These cognitive skills are in line with the top levels of the categories of cognitive process dimensions (analyse, evaluate, create) in Bloom's revised taxonomy, a scheme for classifying educational goals and objectives (Krathwohl 2002). The present study's findings demonstrate that educators associate CT in ECEC more explicitly with children's personal dispositions than with their cognitive skills. Although participants emphasise different analytical approaches to solving a given problem (Facione 2011), other CT cognitive skills are given less emphasis. This may reflect the Framework Plans approach, wherein these core CT cognitive skills are assigned less weight than dispositions and attitudes.

The relationship between CT cognitive skills and CT disposition has been studied in different educational fields (Profetto-McGrath 2003; Yang and Chou 2008). Results from these studies found a lower level in CT cognitive skills and a higher level in CT disposition among baccalaureate nursing students (Profetto-McGrath 2003). It has also been demonstrated that an improvement in CT cognitive skills reinforces CT disposition (Yang and Chou 2008). Nonetheless, increased CT disposition does not enhance an individual's CT cognitive skills. As noted, although the participants did not appear to refer directly to cognitive skills, they associated the concept of CT with the ability to solve problems and transfer skills to other contexts. According to Mayer and Wittrock (1996), problem-solving, thinking, and reasoning are interchangeable terms. For example, CT evaluates ideas that could be used to solve a problem, and transfer is the ability to use what was learned to solve new problems. However, the debate on the possibility of transferring CT skills from one domain to another is still open, and there is different empirical evidence that documents both success and failure in the attempt to transfer CT skills and abilities (Lai 2011).

The educators' assertion that introducing children to CT practices from an early age can help them in their educational development and help them encounter the world critically reflects research by Aizikovitsh-Udi and Cheng (2015) demonstrating the importance of the educator's consistent and systematic promotion of CT in their classes to help students practice and develop their CT skills. Jensen (2005) also found that children's early exposure to quality CT skills can stimulate more sophisticated thinking skills in the future.

CT skills and social–emotional learning are closely linked, and CT dispositions positively affect social–emotional learning (Arslan and Demirtas 2016). Research has also demonstrated that CT and self-regulation are positively related to social–emotional learning (Arslan 2018). This study's results appear to corroborate this. Conversely, while the participants emphasised the social and personal aspects while reflecting on CT's relevance to children's development, the participants did not mention the existential and philosophical aspects covered in the Framework Plan (Ministry of Education and Research 2017) during the interviews.

It was interesting that the participants perceived both conflict and collaborative situations as good opportunities for working on the development of children's CT abilities. Conflicts are experiences that can contribute to children's learning in terms of cognitive, social and moral development (Skoglund 2019). Supporting children in the process of explaining their reasons in conflict situations helps them develop consciousness with respect to their thinking and can stimulate their ability to think about thinking in a process often termed 'metacognition' (Conklin 2011). Collaborative learning also increases and promotes CT and, in particular, it fosters the development of CT through discussion, clarification of ideas and evaluation of others' ideas (Gokhale 1995; Karami, Pakmehr, and Aghili 2012).

Conflict and collaboration interactions recall Vygotsky (1978) and the educators' role not only in transmitting information but also in serving as facilitators for learning

(Gokhale 1995; Hanno, Jones, and Lesaux 2021). According to Vygotsky's (1978) socio-cultural theory, mediation plays a key role in cognitive development and effective learning; ECEC educators have the potential to make a significant impact through their role in the mediation process. Children must be active thinkers, and their educators must actively involve them in the thinking process (Conklin 2011). These ideas are interwoven with the concept of the teacher's role in the Reggio Emilia approach: as they observe the children, educators ask questions, discover the children's ideas, hypotheses and theories, and provide occasions for discovery and learning (Gandini 1993). Questions are key to higher-order thinking skills (Conklin 2011) as they are the most powerful teaching tools for increasing the quality of instruction. Questions that require high-level thinking, such as open-ended questions designed to support or exercise children in thinking and problem-solving (Siraj, Kingston, and Melhuish 2015), can foster CT skills in children (Nappi 2017).

Finally, while the Framework Plan (Ministry of Education and Research 2017, 54) suggests existential, ethical and philosophical questions as means of stimulating CT skills, the participants in this study appeared to be more focused on the problem-solving, transference, and social and physical aspects of CT. This is in accordance with research demonstrating that it is more common to associate problem-solving approaches with higher-order thinking skills in education, whereas from a philosophical perspective, it is more common to endorse CT and logical reasoning (Lewis & Smith 1993; Resnick 1987).

Study limitations and future directions

According to the Framework Plan, ECEC centres should help children to develop the ability to think critically, and all the interviewed educators perceived CT as essential in ECEC. They characterised it in connection with various dispositions and attitudes and considered their role to be essential as a form of mediation, supporting children as facilitators. Future research could further explore this heightened attention towards dispositions rather than children's cognitive skills when exploring educators' perspectives on CT. It would also be interesting to investigate whether the Vygotskian theoretical conceptualisation of educators as facilitators who ask open-ended questions and support children in realising their potential is the most helpful theory for understanding the relationships between ECEC educators' perspectives and CT.

Overall, our results represent the perspectives of a small group of Norwegian ECEC educators, who may have responded from a best-practice perspective. With no documentation of their actual practice in kindergarten, we cannot determine the extent to which their perspectives are reflected in their activities with the children. Nevertheless, the study offers insights into how Norwegian early childhood educators approach the concept of CT and contributes to expanding the discussion on the need to stimulate CT in young children.

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Appendix: Interview guide

(1) How many years of teaching experience do you have?
(2) What is your understanding of critical thinking? What does this term mean in the context of young children, particularly in relation to the Framework Plan. What do you think?
(3) Given what you have just said, do you think that some are more important than others when it comes to these skills? Why?
(4) What role do you think these skills play in the daily activities of kindergarten? What is your opinion about supporting children's critical thinking in kindergarten?
(5) How can children benefit from being stimulated to reason, argue and seek solutions in kindergarten?
(6) How can kindergarten teachers work to support and stimulate these skills?
(7) Are there any special activities you or other employees in the kindergarten carry out in the kindergarten to stimulate children's thinking?

Appendix 2 – Study II

nordisk barnehageforskning
nordic early childhood educational research

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Mathematics and higher-order thinking in early childhood education and care (ECEC)

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Abstract
This article investigates the perspectives of Norwegian early childhood educators on mathematics and higher-order thinking. Thematic analysis of the connection between mathematics and children's higher-order thinking skills was performed based on semi-structured interviews with ten educators in three different early childhood education and care (ECEC) centres. The findings suggest that educators, recognising mathematics as vital for ECEC, associate mathematics with problem-solving, an aspect of higher-order thinking skills highlighted in the research literature. The educators identified many opportunities for working with mathematics in daily activities, in accordance with the Norwegian tradition in recent years. Our results provide insights into how mathematics can support early childhood educators' stimulation of higher-order thinking in the Norwegian ECEC context.

Keywords: *critical thinking; higher-order thinking; mathematics; problem-solving; Norwegian ECEC educators*

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Introduction

In the last few decades, mathematics in early childhood education and care (ECEC) has received increasing attention (Sarama & Clements, 2008; Ten Braak et al., 2022), and the importance of working with mathematics in the early years has become evident. Recent research indicates that children's early mathematical skills can have lasting effects on both future mathematical development and other subject areas (Lenes et al., 2020;

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Ten Braak et al., 2022). This has laid the foundation for an increased interest in stimulating children's mathematical development in early childhood (Baroody et al., 2019; Johnston & Bull, 2021; Sarama & Clements, 2008). Moreover, working with mathematics is seen as an opportunity for children to learn to think and develop higher-order thinking skills (Anderson, 1994; Hobri et al., 2018). These efforts build on the theoretical idea that educators, as supportive adults, can help children identify and elaborate upon concepts that they already know, beyond the level that the children may have achieved without the educators' help (Smith, 1998).

The importance of working with mathematics was not highly prioritised in Norwegian ECEC until the new *Framework Plan for Kindergartens* was introduced in 2006 (Ministry of Education and Research). In this plan, well-established ECEC traditions were confronted with a new learning area, 'Quantities, spaces and shapes', which focuses on exploring and discovering mathematics (Ministry of Education and Research, 2006; Østrem et al., 2009). In this context, the Norwegian *Framework Plan* has drawn attention to the crucial role of educators in teaching and supporting mathematical learning and thinking in young children (Ministry of Education and Research, 2017). This political priority in Norway builds upon a broad consensus in the research literature that educators play an essential role in developing mathematical skills in children (Benz, 2012; Bobis et al., 2005; Chen et al., 2014; Thiel, 2010).

In a previous study (Pollarolo et al., 2022), we investigated Norwegian early childhood educators' perceptions of critical thinking as a higher-order thinking skill. The findings showed the propensity of educators to identify critical thinking as being crucial for children's development and their role as essential in supporting and stimulating critical thinking in children. The educators described critical thinking more in relation to a child's disposition and attitudes than to cognitive skills and connected it mainly with social and physical aspects.

In order to develop more knowledge about the relationship between mathematics and higher-order thinking skills, the current paper investigates Norwegian educators' perspectives on their mathematics pedagogy and their views on the relationship between mathematics and higher-order thinking. Understanding educators' perspectives is important in identifying both challenges and successful approaches to developing children's higher-order thinking skills in ECEC.

Background

The early years of life play an essential role in children's cognitive, language and educational development (Melhuish et al., 2015). Three topics, including early mathematics, literacy and aspects of self-regulation, have been the main focus of ECEC research, as they are highly predictive of children's later school success (Duncan et al., 2007). In this respect, the importance of mathematics in ECEC has been widely discussed in the literature, and there is a consensus about the potential of working with mathematics in the early years and its association with later achievements (Duncan et al., 2007; Geary et al., 2013; Watts et al., 2014), not only in mathematics but also in other areas (Claessens & Engel, 2013; Ten Braak et al., 2022).

However, despite research efforts in specific areas in ECEC, an emphasis on skills that allows children to connect factual, conceptual and procedural knowledge (as defined by Anderson and Krathwohl (2001)) to metacognitive knowledge appears to be missing. This would involve developing the skills that enable children to use and connect information in a meaningful manner and assisting them in approaching new learning areas. In other words, we need to focus on developing children's higher-order thinking skills, which are essential considering our rapidly changing and challenging world and the efforts towards a more sustainable future. Therefore, higher-order thinking skills are considered as important *21st century skills* (Collins, 2014), and are included in the key competencies in 'Education for Sustainable Development' (Rieckmann, 2018).

Research shows an association between the development of higher-order thinking skills and mathematics (Apriani & Rianasari, 2020; Richland & Begolli, 2016; Tanujaya et al., 2017), and the relationship between the two seems to be reciprocal. Mathematics as content may improve higher-order thinking skills (Hobri et al., 2018), and mathematical skills may also be enhanced through the promotion of higher-order thinking skills (Pratama & Retnawati, 2018; Tajudin & Chinnappan, 2016). However, there is scant evidence of this connection in ECEC.

Previous research has drawn attention to the crucial role of educators in teaching and supporting mathematical learning and thinking in young children. The mediation role provided by educators enhances children's propensity for learning (Howie, 2019). Educators' roles as supporting adults require teaching beyond formal mathematics, which means moving from traditional teaching approaches—in which the teacher is in charge of showing and explaining—to a function of open guidance in helping children develop their own thinking (Anghileri, 2006). Thiel (2010) demonstrated a correlation between educators' beliefs and knowledge of mathematics and their attitudes towards it, and suggested that it is essential to foster mathematics learning in ECEC teacher education to support educators' positive perspectives towards it. Various studies have described constructive attitudes and openness among ECEC educators towards mathematics and confidence in mathematics teaching in the early years (Benz, 2012; Chen et al., 2014; Thiel, 2010).

In the context of our study, we define 'perspectives' as educators' evaluations and reflections related to young children's mathematical and higher-order thinking skills. In this general definition, 'perspectives' is similar to the term 'conception' used by Philipp (2007), which includes 'beliefs, meanings, concepts, propositions, rules, mental images, and preferences' (p. 259).

Higher-order thinking

Higher-order thinking can be framed or described in different ways. Conklin (2011) argued that higher-order thinking skills incorporate critical thinking and creative thinking. Resnick (1987a) claimed that, depending on the approach, we can focus on different aspects. From a philosophical perspective, the emphasis is on critical thinking and logical reasoning. While developmental psychologists tend to highlight the significance of metacognition, cognitive scientists focus on cognitive strategies and heuristics. Furthermore, educators tend to promote problem-solving. From this perspective, Resnick (1987a) herself noted that although it is impossible to provide a precise definition of higher-order thinking, it is immediately recognisable when we encounter it.

The idea of higher-order thinking that can be perceived in different ways is well-represented by Miri et al. (2007). These authors used 'higher-order thinking' as an umbrella term encompassing different categories of thinking. In this context, Brookhart (2010) synthesised the definitions of higher-order thinking into three different categories: those that define higher-order thinking in terms of *transfer*, those that define it in terms of *critical thinking*, and those that define it in terms of *problem-solving*. This distinction demonstrates how higher-order thinking can manifest in different ways.

Critical thinking is often considered a domain of the humanities and problem-solving a domain of the sciences and mathematics (Lewis & Smith, 1993). However, there is no rigid demarcation line between problem-solving and critical thinking, as they are intertwined. For example, problem-solving is also defined as a particular kind of critical thinking (Willingham, 2007). More recent approaches define critical thinking as inevitably preliminary in the process of solving a problem and argue that real problems can be resolved only with the support of critical thinking, which can generate new knowledge, since it engages in deeper complex thinking (Voskoglou & Buckley, 2012). When involved in solving a problem, one has to evaluate the problem using and adapting previous knowledge and skills, and thinking at a higher level; this is considered the first step in using critical thinking (Doleck et al., 2017).

Some previous studies have investigated the connection between critical thinking and mathematics (e.g. Aizikovitsh & Amit, 2010; Sachdeva & Eggen, 2021), but few of them are at an ECEC level (Aizikovitsh-Udi & Cheng, 2015; Pollarolo et al., 2022; Schillinger, 2021).

Aims of the study

The purpose of this study is to examine educators' perspectives on mathematics and the elements of higher-order thinking skills foregrounded in the ECEC context when the focus is on mathematics. This work is part of a larger body of research focused on higher-order thinking in Norwegian ECEC (Pollarolo et al., 2022). The research question we ask is as follows:

> *What are educators' perspectives on mathematics and the connection between mathematics and higher-order thinking skills in the ECEC context?*

Method

Participants

The data for this paper originate from interviews conducted for a larger project that involved the participation of three different ECEC centres. By the term 'ECEC centre,' we refer to the Norwegian *barnehage*, which means premises used for educational and care activities with children aged one to six years before compulsory school. The centres were selected due to their previous collaborations with the University of Stavanger. Information about the study was provided to the three ECEC centres, and ten educators, including eight pedagogical leaders and two educators working with children with special needs, agreed to participate in semi-structured interviews. Before starting, informed consent was obtained from all participants. The average participant's working experience in ECEC centres was 17 years, ranging from a minimum of 1.5 years to a maximum of 35 years. Eight educators had 15 years or more of working experience, which means that they started working at the centre before or at the time of the 2006 revision of the *Framework Plan for Kindergartens*, which introduced a requirement for increased focus on mathematics in ECEC (Ministry of Education and Research, 2006).

Ethical considerations were presented to and approved by the Norwegian Centre for Research Data (NSD).

Study procedure

Three pilot interviews with ECEC professional personnel at the University of Stavanger were conducted to test, verify and adjust the interview questions before finalising the interview guide (Appendix). All the participants received the interview questions a few days before the interview. Therefore, they had the opportunity to reflect on the topic in advance.

The interview guide was divided into two sections. The first section focused on the educators' perceptions of critical thinking as one of the higher-order thinking skills, and the second focused on mathematics. The questions were designed to align with the subjects in the *Framework Plan* (Ministry of Education and Research, 2017). Due to the volume of the data collected, this article focuses on the second half, which concerns educators' perceptions of mathematics and the connection between mathematics and higher-order thinking. The topic of the first half is the subject of another article (Pollarolo et al., 2022).

Interviews

The participants were interviewed in person at their own ECEC centre. The interviews lasted between 20 minutes and an hour and were audio-recorded and transcribed. After the transcription, a native Norwegian speaker performed proofreading to identify any discrepancies between the audio recordings and the transcriptions. Each participant received a copy of their own interview, and they all approved the content.

Analysis

The interview transcriptions were analysed using thematic analysis, a method widely used for analysing qualitative data (Terry et al., 2017). Braun and Clarke (2006) defined thematic analysis as 'a method for identifying, analyzing, and reporting patterns (themes) within data' (p. 79); to this end, our analysis followed the six steps suggested in the guidelines provided by Braun and Clarke (2012). The transcripts were first read several times before coding to allow the authors to familiarise themselves with the data. Handwritten notes were taken during reading. Next, with the help of the software NVivo 12, a systematic coding of the transcripts was conducted in four stages: descriptive, *in vivo*, process and concept coding (as proposed by Saldaña (2021)). The codes were then condensed into themes in an effort to encapsulate the educators' opinions and practices regarding mathematics and higher-order thinking. After the initial definition of the themes by the first author, all authors discussed and reviewed the themes in several rounds until a final version was agreed upon. Eventually, three themes and nine subthemes were defined. Brief quotations from the transcriptions were selected to provide examples and better describe each theme. The quotations were translated from Norwegian to English. To ensure anonymity, the individual educators are referred to as Educators 1–10.

Findings

As depicted in Figure 1, the data analysis resulted in three main themes. Each theme has three subthemes, which capture different aspects of the main theme. The first theme captures the educators' perception of mathematics as the ability to solve problems. The second theme underlines the broad consensus among educators about the abundant opportunities to work with mathematics. The third theme encapsulates the educators' opinions related to their own experiences in learning mathematics.

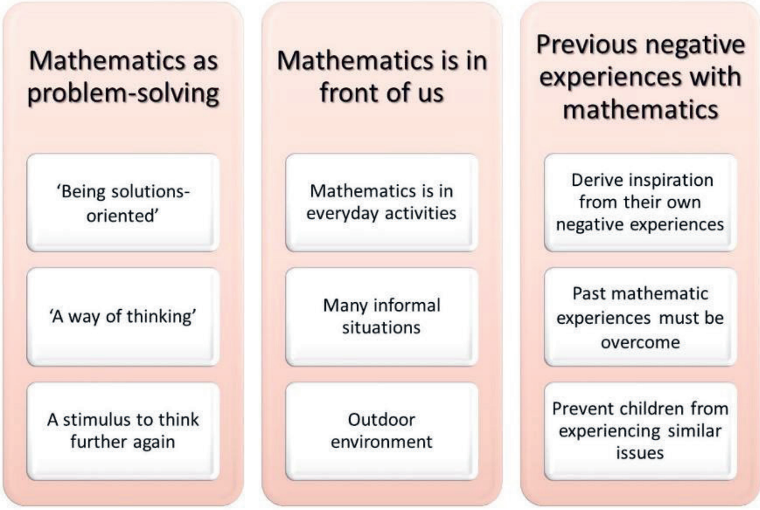

Figure 1. Themes identified through the analysis of the semi-structured interviews.

Mathematics as problem-solving

Based on the analysis, it appears that the participants perceived mathematics as a means of thinking or solving problems or as a solution-oriented approach to life. According to them, mathematics stimulates more extensive connections and helps children think further.

Half of the participants associated mathematics with the concept of being able to solve problems and being 'solutions-oriented' (Educator 1), because it is essential for educators to 'help them [children] to see solutions' (Educator 4) and, in order to find solutions, 'they need to think deeply' (Educator 9). 'I think that mathematics is about discovering and exploring to understand. It is a way of thinking, a language to solve problems according to contexts, to develop the ability to think for yourself' (Educator 1).

The same educator also found it crucial to work with mathematics in ECEC because, in this way, children could practice their abilities to solve problems and then as adults, in their working life, they would not be afraid 'to become engaged in new things'.

According to the participants' opinions, mathematics 'stimulates one to think further' (Educator 10), and it is connected with problem-solving because mathematics means 'reasoning about different paths and arriving at the goal' (Educator 1) or, as Educator 5 stated, 'It is to think about problem-solving, as it is to create different paths to develop further'. Therefore, mathematics is a language for solving problems and is essential for inspiring children to find a solution together and then enable them to find solutions by themselves.

Educator 4 highlighted the importance of transcending the intrinsic meaning of mathematics as a given form or number and recognising that there are different ways of doing things: 'to be able to see solutions, that they should also be able to see that there are many different ways of doing things, that they must not be stuck to a given form, given number.'

Mathematics is in front of us

The findings reveal a wide consensus among participants that there are many opportunities to work with mathematics in everyday life. As described by the participants: 'I think that mathematics is in everyday activities; it's right in front of us; it's in songs, in rhymes, in fairy tales' (Educator 3); 'I think everything around us actually [...] I see the importance of them [children] seeing that there is really mathematics in everything we do, in a way' (Educator 6).

The notion that mathematics is everywhere is deeply rooted among the participants, all of whom mentioned it. Educator 7 highlighted this when she stated: 'It surprised me how much math there really is; you become aware of everything you did that was math that you had not thought of before, that it appeared to be just play, but there is learning.'

In this regard, educators stressed that the mathematical activities they engaged in at the ECEC centre are frequently not identified specifically as mathematics. The opinion of the participants was that, even though educators know that the activity they are doing involves mathematics, there is no need to emphasise this to the children. Some participants described informal situations or activities in which mathematics could be involved, such as reading a book or cleaning up a table. In relation to this common idea that mathematics is everywhere, six participants focused in particular on the outdoor environment as an arena for implementing mathematical activities. The participants mentioned different materials and activities, including picking up pine cones and sticks of different lengths to build shapes. They believed that the availability of these materials in nature offers many opportunities to apply mathematics differently to how they apply it indoors in the ECEC centre. Moreover, their opinion was that an outdoor setting provides more opportunities for the children's free expression and more space where they can test techniques and concepts. Most of the participants—namely, 6 out of 10—posited that the expositions we give to children influence their approach to critical thinking and mathematics. Therefore, the environment plays an important role, particularly the environment at the ECEC centre and at home, including parents' education and engagement, as pointed out by Educator 3: 'it is the environment they have at home ... children often have parents at home who are very interested.'

Among other mathematical activities, approaches related to problem-solving in everyday situations were described by the participants. Educator 4 stated, 'It's also about how we will put things together so that something will come out of it.' Educator 1 also spoke about working with '*rom og retning*' (Norwegian for 'space and direction'): 'What we do inside here, if we were going to build a cabin, how much would we need?'

Previous negative experiences with mathematics

Some of the educators admitted that they themselves did not have positive mathematics experiences during their time at school. Nevertheless, these educators believed that they had to derive inspiration from their negative experiences and work to prevent children from experiencing similar issues once they reached school. This is exemplified by the following quote: 'Maybe just because I had a bad experience with school mathematics, it made me a little interested in that: how can we avoid kids having to sit and have it the same way at school as I did?' (Educator 6).

The participants believed that their own past negative experiences must be overcome to avoid being affected by them in their approach to children's mathematical education. Most of them did not experience any challenges when working with mathematics in ECEC. The only challenges some of the educators underlined were linked to the need for educators to be aware of the importance of working with mathematics in daily life and the ability to eliminate their negative preconceptions. As Educator 9 put it, 'You carry with you a story yourself, your experiences and thoughts about mathematics. I have always struggled with mathematics at school […]. But this is on a whole different level, and you have to put it away. It still affects you. So maybe many people think it's difficult.'

Although some educators reported some negative experiences with mathematics from childhood, the results illustrate an open and positive perspective towards mathematics in ECEC. All the participants answered positively when asked about their opinions concerning the benefit of children working with mathematics in ECEC, and they underlined the importance of starting as early as possible.

Discussion

This study investigated Norwegian ECEC educators' perspectives on mathematics and higher-order thinking. Interviews with ten ECEC educators showed that they perceived mathematics as important in ECEC, identified diverse opportunities for working with mathematics in everyday activities, stressed the importance of eliminating previous negative preconceptions and perceived a clear connection between mathematics and problem-solving, which is an aspect of higher-order thinking.

The purpose of this study was twofold: to establish (i) educators' perspectives on mathematics; and (ii) the connection between mathematics and higher-order thinking skills. When it comes to the first aim, the Norwegian educators appeared confident about the importance of mathematics in ECEC and had an open and positive perspective towards it. This is in line with previous research from Germany and the US (Benz, 2012; Chen et al., 2014; Thiel, 2010). Still, during the interviews, some of the educators reflected on their negative personal experiences with school mathematics, and they were aware of the importance of trying not to let this influence their daily work with the children in ECEC. To manage the possible challenges connected to mathematics in the ECEC context, it is important that educators think positively about their own mathematical skills and abilities (Jenssen et al., 2020). Furthermore, attitudes matter, as demonstrated by Lee (2005), who showed that educators' attitudes towards teaching mathematics were significantly associated with the practice of developmentally appropriate mathematics.

In the present study, the participants' positive approach to teaching mathematics was also reflected in their perspective that daily life is rich in opportunities to apply mathematics generally and problem-solving specifically. The idea that mathematics is everywhere can be traced back to Sumpter (2020) research on Swedish preschool teachers' conceptions about mathematics and emotional directions towards mathematics. In the present study, this idea can be seen in connection with the Norwegian ECEC tradition, in which learning opportunities are considered to arise from different pedagogical situations. Such situations can be activities initiated by the educators or more spontaneous child-initiated activities arising from everyday situations in which the educators focus on following the child's interests (Ministry of Education and Research, 2015). According to Skarstein and Ugelstad (2020), ECEC educators value the outdoors as an environment that provides many opportunities for such spontaneous activities. In the present study, the educators also viewed the outdoors as an important arena for working with mathematics and regarded it as an arena with more nature-related opportunities for children's free expression and for applying mathematics in more varied ways.

This positive result is also in line with the Norwegian ECEC policy which, from 2006 onwards, has led to great efforts to support and implement mathematics in ECEC from the point of view of both the *Framework Plan* (Ministry of Education and Research, 2017) and educators' training. Recognising that mathematics can be present in everyday circumstances and integrating mathematics learning into play helps educators to support children in acquiring confidence and positive experiences in mathematics (Björklund, 2012; Johnston & Bull, 2021).

The results particularly reflect the learning area 'Quantities, spaces and shapes' in the *Framework Plan*, which focuses on exploring and discovering mathematics in everyday life, guides educators to 'stimulate the children's sense of wonder, curiosity, and motivation for problem-solving' and highlights the importance of 'asking questions, reasoning, argumentation and seeking solutions'. Educators are also expected to 'stimulate and support the children's capacity for and perseverance in problem-solving' (Ministry of Education and

Research, 2017, p. 54). In connection to Bishop (1989), six universal mathematical activities—adjusted to Norwegian ECEC by Solem and Reikerås (2001)—problem-solving can be traced back to the 'Explanation and argumentation' category.

As for the educators' perspectives on the connection between mathematics and higher-order thinking skills, our results showed that half of the participants associated mathematics with being problem-oriented and able to find solutions. In relation to the three aspects of higher-order thinking mentioned by Brookhart (2010), educators are more problem-solving-oriented when mathematics is involved (Resnick, 1987b). The present study also supports this idea in the ECEC context: the educators' answers appear to suggest that supporting higher-order thinking through mathematics in ECEC means acting on the ability to solve problems. The association between the ability to think critically and the ability to solve problems has been pointed out earlier by, for example, Snyder and Snyder (2008), who highlighted critical thinking as a condition for being able to resolve problems in a successful and effective manner.

In the context of learning mathematics, previous research has shown that early learning in children is better facilitated by the problem-solving process and logical reasoning than by teaching specific mathematical knowledge (Perry & Dockett, 2008; Reikerås et al., 2012). It follows that working with mathematics means developing problem-solving skills which do not develop separately from critical-thinking skills.

In our previous study (Pollarolo et al., 2022), the same educators, when interviewed about critical thinking in general (and not related to any specific subject), focused more on the children's attitudes and dispositions than on their cognitive abilities. Yet, critical thinking can be defined as the sum of two components: cognitive skills (or abilities) and dispositions/attitudes (Lai, 2011). According to Lai (2011), while philosophers focus more on the characteristics of the ideal critical thinker, or rather on those dispositions and attitudes that define the hypothetical critical thinker, cognitive psychologists focus more on the product of the thought or the types of actions or behaviours of the critical thinkers. In other words, the focus is on the mental and cognitive skills, such as analysis and interpretation, that people employ to solve a problem. From the educators' answers to questions related to mathematics, it appears that the educators' perspectives are oriented towards problem-solving skills. This reflects the idea that, when placed in a particular context or a particular domain, such as mathematics, educators are more focused on aspects of thinking defined as abilities as opposed to disposition and attitudes. When looking at the results of our two studies together (Pollarolo et al., 2022, and the current study), it seems that when interviewed about critical thinking in general, the educators focused more on attitudes and dispositions, but when the interviews turned their focus to mathematics, the educators shifted their focus to cognitive abilities. Therefore, we can consider mathematics as a domain that can integrate the social and emotional aspects of higher-order thinking skills with the more cognitive approach typical of mathematics. This finding contributes to a more holistic approach to fostering these essential skills in children.

Conclusion and future research

This study aimed to explore ECEC educators' perspectives on mathematics and the relationship between mathematics and children's higher-order thinking development. As a theoretical implication, the findings support the idea that, when considering the connection between higher-order thinking skills and mathematics, educators mainly focus on problem-solving abilities. Interestingly, in our previous study (Pollarolo et al., 2022), when the focus was on critical thinking in general, the educators connected higher-order thinking to dispositions and attitudes. This reflects the idea that higher-order thinking can be perceived in different ways and encompass different categories of thinking (Miri et al., 2007) and, as our study suggests, this may be dependent on the domain.

Although several educators had negative experiences with mathematics in their childhoods, they showed a positive propensity towards teaching mathematics in ECEC, which is a good precondition when using mathematics to develop thinking abilities and skills. The findings also support the idea that higher-order thinking can be developed within a specific content—in the case of this study, the content being mathematics (Davies, 2006; Dewey & Bento, 2009).

The lack of investigation into actual practice does not allow us to make any claims about the relationship between educators' perspectives and actual practice in their settings. However, while our sample size was limited, our findings provide insights into the possible means by which mathematics can be used as a domain for higher-order thinking development among children in ECEC. In terms of the *Framework Plan* (Ministry of Education and Research, 2017), ECEC teacher education and ECEC educators' professional development, the results of our study highlight a need for more focus on the importance of developing children's higher-order thinking skills. Identifying specific pedagogical practices and their relationship to children's skills remains the goal of future research.

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Appendix: Interview questions

1. Now, I would like to change the subject to mathematics. If I say mathematics and kindergarten, what is the first thing that comes to mind?
2. The *Framework Plan for Kindergartens* states that 'Kindergartens shall highlight relationships and enable the children to explore and discover mathematics in everyday life'. What does this mean, in your opinion?
3. So, do you / don't you think that children can benefit from working with mathematics, already in kindergarten?
4. Do you usually have any difficulties in working with mathematics? If yes, why?
5. Are there any preferred activities you do when working with mathematics?
6. Which areas within mathematics do you intend to stimulate through your activities?
7. I am specifically interested in the learning area 'Quantities, spaces and shapes' and I wonder whether you have ever considered that area in your practice in kindergarten and how.
8. What is your opinion on using mathematics to stimulate children's ability to think critically?
9. Are there any differences in relation to specific characteristics of children, for example, gender, culture, temperament and their thinking skills and or mathematics?

Appendix 3 – Study III

Play with Coding Toys in Early Childhood Education and Care:

Teachers' Pedagogical Strategies, Views and Impact on Children's Development.

A Systematic Literature Review.

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PLAY WITH CODING TOYS IN EARLY CHILDHOOD EDUCATION AND CARE

Abstract

This paper presents a systematic literature review that aims to portray an overview of pedagogical strategies that Early Childhood Education and Care (ECEC) teachers adopt to support children's play with coding toys. In addition, the article synthesizes findings about teachers' views in relation to the use of coding toys in ECEC and describes the outputs that the existing literature identifies as children's development after play activities with coding toys. The importance of such play for fostering 21st-century skills, such as computational thinking, problem-solving and critical thinking, has long been recognised, and teachers play a central role in facilitating it. Although the literature presents the central role of the teacher in supporting children's learning during the use of coding toys, there is no evidence of studies providing a synthesis of the ECEC teachers' pedagogical strategies. The systematic literature search was performed in accordance with the PRISMA-2020 statement, and the initial search across four databases (Eric, Scopus, Web of Science, and Academic Research Ultimate) for papers published between January 2010 and May 2022 yielded 2672 peer-reviewed articles. Following the first evaluation, the application of the inclusion and exclusion criteria resulted in a shortlist of 22 papers. The results show different strategies that the teachers can use during play activities with coding toys, assuming the roles of facilitators and mediators through collaborative work, allowing children to try and fail.

Moreover, the results revealed that ECEC teachers largely hold positive and constructive attitudes towards the use of coding toys. Findings also highlight positive outcomes regarding children's development across various cognitive and socio-emotional areas. As an improvement, future studies should focus on identifying appropriate pedagogies that may be applied in tandem with the technology to maximise the pedagogical benefits for the children as well as adequate training for teachers.

Keywords: coding toys, computational thinking, early childhood education and care, teachers' pedagogical strategies, problem-solving.

PLAY WITH CODING TOYS IN EARLY CHILDHOOD EDUCATION AND CARE

1 Introduction

Technological developments in recent decades have highlighted the need to educate children to navigate the rapidly developing digital society in which they are growing up from a young age. As such, the integration of technology into early childhood education and care (ECEC) has become a key focal topic for researchers (Clarke-Midura et al., 2019). Technological advancement has led to the proliferation of tools that facilitate the introduction of coding activities and computational thinking to young children, and several countries, including England, Australia and Finland, have incorporated coding into their early years education programmes (Rich et al., 2019).

Coding toys is a term used for identifying toys with the form of a robot that claims to help young children learn computer programming. The coding toys are robots that a child programs to move forward, backwards or turn right or left (Clarke-Midura et al., 2021).

Coding toys may consist of physical, virtual or hybrid kits (Yu & Roque, 2019) as well as, more generally, educational robots representing the tools and materials that allow the successful implementation of computational thinking (Catlin & Woollard, 2014). The use of digital tools of this nature in early childhood education has numerous benefits; specifically, they can initiate children's coding abilities and foster their computational thinking skills (Yang et al., 2020), which are skills that not only relate to programming or computer science but also involve various mental competencies, from problem-solving to critical thinking and understanding human behaviour (Wing, 2006). Therefore, among the various types of play in which children engage, those that involve coding may be considered essential stimuli for 21st-century skills, such as creative and critical thinking, questioning and problem-solving (Çiftci & Bildiren, 2020; Granone & Reikerås, 2021), and for the so-called higher-order thinking skills (Zaharin et al., 2018).

When using coding toys—and indeed technology of any type—with children in ECEC, it is essential to consider the teaching staff's knowledge of technology and associated pedagogy practices (Wang et al., 2021). Teachers play a fundamental role in implementing coding toys in early childhood education; hence, acquaintance with teachers' pedagogical approaches and opinions is paramount. While studies focus increasingly on how computational thinking and coding have been employed in early childhood education (Bati, 2022; Macrides et al., 2021; McCormick & Hall, 2021), teachers' pedagogical strategies for the implementation of coding activities in ECEC remain relatively overlooked. Therefore, this systematic literature review aims to shed light on teachers' pedagogical strategies and views in supporting early children's 21st-century skills during activities with coding toys. More specifically, based on evidence from empirical studies, this study investigates the teachers' pedagogical strategies, including their views, and the types of skills detected or expected in children as output after implementing those activities.

2 Related Research

In recent years, systematic literature reviews have been increasingly conducted with the aim of enhancing scientific knowledge on the use of coding toys or, more generally, of coding activities, both plugged and unplugged. Those reviews have various focal topics, with several seeking to evaluate the efficacy of the various technologies. Papavlasopoulou et al. (2017) demonstrate that tangible programming languages offer many opportunities for fruitful learning experiences for children, while for instance, González-González et al. (2019) investigated the use of tangible technologies in early childhood education to identify the types of technologies used and their educational purposes, uses and effectiveness. They found that a range of tangible technologies are used in early childhood education, including robots. Other technologies include tablets, portable computers, cameras, the Internet of Things, wearables and software, such as apps, e-books, and digital games. They observed that coding is considered an essential subject in early childhood and that children can develop the ability to code through robot manipulation. Johnson et al. (2017) also focused on the different types of technologies used, their applications and their effectiveness as learning tools in early childhood education. The authors found that, owing to a lack of appropriate communication and understanding of developmentally appropriate tools in the marketing and engineering fields, those tools are not adequately developed and used with the correct age groups. This can lead to inappropriate and ineffective use of these tools. Another finding that has emerged is the possibility of not only introducing programming to children as a discrete subject but also embedding it in various other subjects on the ECEC curriculum, including music, movement, dance, art, science, mathematics and literacy (Macrides et al., 2021).

Other studies have reviewed the application of educational robots in school contexts. Kubilinskienė et al. (2017) analysed the use of robotics in primary and secondary schools and in informal education, such as after-school clubs or summer camps. Their literature review reported a continuous growth of robotics in schools regarding the types of educational robotics tools and learners' age ranges. Although these studies' target samples are typically in the early childhood age range, Jung and Won (2018) included international studies that focused on participants up to 6th grade (11 years) due to the low number of studies targeting early children. In addition, the results of the literature review conducted by Zhong and Xia (2020) showed that the age of the participants in the selected articles varied from 3 to 33, but the largest sample groups were elementary and secondary school students. Moreover, their systematic review aimed to explore the application of robotics in mathematics education. Different systematic reviews have focused on the application of robots in various subjects. In this respect, Jung and Won (2018) characterised previous studies' focus on robotics education exclusively as an instrumental tool to support other subjects or science, technology, engineering, arts and mathematics (STEM) education as a limitation.

Other reviews focused on how the use of educational robotics affected the participants' skills development. Mich et al. (2021) found that several studies demonstrated that children aged between 3 and 6 years can acquire and develop coding abilities, including computational thinking, algorithmic thinking and problem-solving. Similarly, Theodoropoulou et al. (2021) observed that educational robotics supports the development of 21st-century skills and can be used to teach various subjects at different education levels, including early childhood. Others have also reviewed the panorama of teacher training programmes in educational robotics from pre-school to secondary schools (Schina et al., 2021).

McCormick and Hall (2021) presented a scoping literature review on computational thinking learning experiences in pre-school settings and demonstrated that most of the studies analysed focused on learning sequences and events, with little exploration of how the relevant skills could be remixed and reused. Bati (2022) applied plugged versus unplugged activities, age and gender aspects as variables and found that while age is significant, both genders perform equally well, and unplugged applications appear to outperform the plugged alternatives by virtue of their greater experiential properties.

Despite the importance of the teacher's role in supporting children's learning in ECEC, to the best of our knowledge, an overview of the ECEC teachers' pedagogical strategies is missing.

In line with the burgeoning interest in the use of coding toys in early childhood education teaching practices, this systematic literature review seeks to investigate pedagogical strategies and views in addition to the skills that their early childhood pupils develop or are expected to develop through the use of coding toys.

'The present study is guided by the following research questions:

RQ1: What are early childhood teachers' views regarding coding toys in ECEC?

RQ2: What pedagogical strategies do early childhood teachers use to support children in playing with coding toys?

RQ3: What detected or expected consequences have been identified with respect to children's skills development as a result of playing with coding toys?

3 Methodology

In this systematic literature review, we followed the PRISMA-2020 statement described in the following paragraphs to answer the above-mentioned research questions (figure 1).

3.1 Data Collection

We consulted the following international databases to identify relevant studies: Eric, Scopus, Web of Science, and Academic Search Ultimate. Those databases were chosen because they were recognized as the most pertinent for identifying literature related to the use of technology in ECEC. The period examined was from January 2010 to May 2022. The search string, including the main key terms, was as follows: (programming OR coding OR computational thinking OR robot*) AND (kindergarten OR pre-school OR early childhood OR children) AND teaching. We used Google Scholar and applied the snowball method to ensure that all major references on the topic were included.

3.2 Inclusion and Exclusion Criteria

Owing to the different file download processes across the various databases, the deduplication process was performed using Zotero software. The total number of records identified following deduplication was 2670.

When the 2670 studies were imported into Rayyan software, the first and third authors evaluated them based on their titles and abstracts applying the following inclusion and exclusion criteria:

Inclusion criteria

- The study context is ECEC (which indicates children's age from one to six).
- The study includes activities performed by teachers or teachers' views about the use of coding toys.
- The study includes activities with coding toys.
- The study is written in English.
- The study is an article.
- The study is published in a peer-reviewed journal or peer-reviewed conference proceedings.

Exclusion criteria

- The study context is not ECEC (children over six years old).
- The study describes activities that are performed by researchers without including the teachers.
- The study describes activities that are based on other technologies then coding toys (such as

apps or tablets).

- The article is not peer-reviewed.
- The study is a meta-analysis, discourse analysis or (systematic) literature review.
- The study is a book chapter.

The screening process excluded 2420 studies. The full texts of the remaining 250 studies were assessed by the first and the second authors, who retained studies focusing on ECEC teachers' use of robots and excluded studies that involved children aged above 6 years (school context), studies relating to humanoid robots and studies that focused exclusively on iPads/tablets. Both researchers used Rayyan to access the same file. The independence of the evaluation was guaranteed by the option 'blind on' provided by Rayyan, which prevents the users from viewing the other researcher's assessment. The two authors resolved the conflicts from this independent evaluation (180 articles).

The five remaining conflicts were collaboratively resolved by all authors, resulting in a final sample of 20 articles. Two more articles have been added following citation searching. To qualify for inclusion, articles had to satisfy quality criteria—for example, publication in peer-reviewed venues, relevance of topic, definition of a clear research question, appropriate choice of method in accordance with the empirical data, presentation of an exhaustive discussion of the findings in relation to the original research question and good reliability and validity levels. Ultimately, 22 relevant studies were selected for inclusion.

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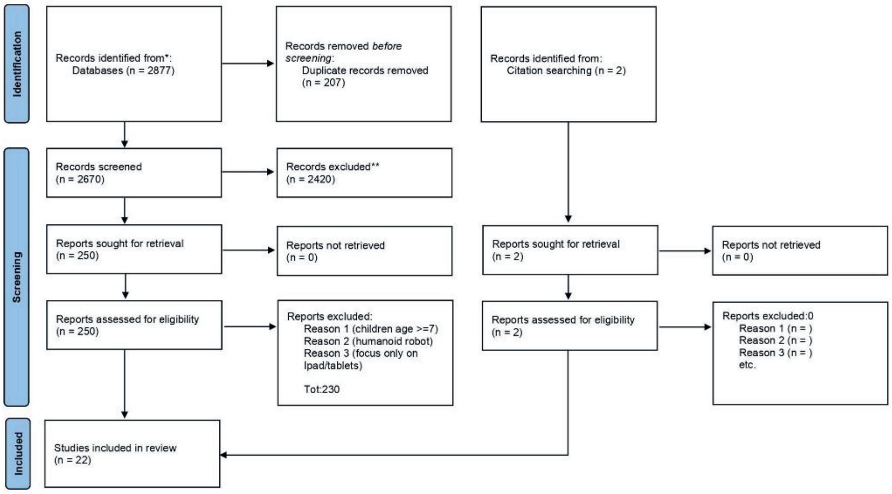

Figure 1

PRISMA 2020 Flow Diagram for New Systematic Reviews, Which Included Searches of Databases and Registers Only

3.3 Data Analysis

The study's synthesis was narrative, and the analysis was thematic (Grant & Booth, 2009). The collected studies were analysed based on the following areas of focus: the methodology used, the instruments, the areas of interest, the type of activities, the number of participants, the duration of the study, the materials used, the training, the activities, the pedagogical strategies, teachers' views and children's detected or expected skills (Appendix A, Appendix B and Appendix C). The authors held consensus meetings to review and approve each step of the analysis, largely conducted by the first author. The data extracted from the 22 studies included in the tables (Appendix A, Appendix B and Appendix C) directly addressed the research questions.

4 Research Findings

4.1 General Characteristics of the Included Studies

First, we present the general characteristics and descriptive statistics of the 22 studies that were analysed.

The results indicate a significant spread in terms of international representation, with 12 different countries represented. The countries that occur most frequently are Sweden (5 studies), the US (4 studies), Spain (3 studies) and Taiwan and Turkey (2 studies each). Australia follows with 1 study (Appendix C).

The search for relevant studies covered the period from 2010 to 2022; however, the results show that the studies publication is largely concentrated in the last five years, peaking in 2020 (2022 is only partially represented, given that it includes only the first five months of the year).

The methods used were predominantly qualitative (12 out of 22 studies). Mixed methods and quantitative analyses were applied in five studies each (table 1).

Table 1

Methods Used in the Studies and instruments for data collection

Method	Number of studies	Percentage	Instruments
Qualitative	12	54.5 %	1 Case study 8 Observations 1 Observations + interview 1 Interview 1 Teacher's Notes
Quantitative	5	23.8 %	Questionnaires
Mixed methods	5	23.8 %	2 Questionnaires + interviews Questionnaire + observations +interview Performance assessment + interviews Questionnaires + Observations

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Our search considered only studies that pertained to plugged activities. However, in the selection, ten studies applied both plugged and unplugged activities (Appendix A).

The number of teachers in the reviewed studies varied and it ranged from 1 to 199, with two emerging as the most frequently occurring value (mode), with four appearances. More than half of the studies (twelve) were in the 1–10 category (table 2).

Table 2

Number of Teachers

Number of teachers	Number of studies	Number of teachers	Number of studies
1–10	12	91–100	1
11–20	2	190–200	2
21–30	2	Not specified	1
80–90	1		

Regarding the number of children involved, six studies did not involve children (table 3). The remaining 16 are categorised as follows:

Table 3

Number of Children

Number of children	Number of studies	Number of children	Number of studies
1–10	6	50–60	1
11–20	4	90–100	1
21–30	1	170–180	1
31–40	1	Not specified	1

The minimum number is 1, and the maximum is 172. The most frequent value was eight children with two appearances.

Towing to the considerable typological heterogeneity of the methods applied in the studies, it was difficult to gather information regarding the studies' duration and specific activities in a way that was significant with respect to the overall picture. Three studies originated from the same three-year project, while the others varied from three days to five months. The activities in the studies lasted between one and ten hours.

In 9 of the 22 studies, the participants (teachers in eight studies, children in one) had received training prior to engaging the activities.

The section that follows presents a synthesis of the results based on our analysis of the 22 studies in line with respective research questions.

RQ1: What are early childhood teachers' views regarding coding toys in ECEC?

To address this research question, we analysed the fifteen articles included in our literature review that reported pre-school teachers' views with respect to implementing coding, coding toys and robotics in general. Five studies (Erdoğmuş, 2020; Fridberg et al., 2021; Otterborn et al., 2019; Papadakis, 2022; Wang & Wang, 2020) indicated that teachers recognised the importance and benefit of introducing robotics and coding toys in early childhood education. Teachers also attested that robotics can assist them in teaching various subjects (Otterborn et al., 2019; Papadakis, 2022).

We also discussed the constructive approach, which occurs independently of the type of experience or knowledge the teachers have experienced. In three studies (Kewalramani et al., 2020; Papadakis, 2022; Wang et al., 2021), the teachers were willing to implement and use coding toys despite having no expertise or targeted experience. In terms of the teachers' perceptions of their own abilities, two studies (Bers et al., 2019; Ortega-Ruipérez & Lázaro Alcalde, 2022) portrayed them as sufficiently autonomous and confident in their capacity to introduce coding or more general programming. In one study (Saxena et al., 2020), teachers expressed doubt regarding their competence in computational thinking. Simultaneously, however, they reported feeling positive about the use and implementation of computational thinking activities and emphasised that proper training would likely be beneficial for increasing their competence. Supportive training for teachers emerged as relevant in four other studies as a crucial means of enhancing pre-school teachers' overall confidence (Bers et al., 2013; Lavigne et al., 2020; Papadakis, 2022; Saxena et al., 2020); in one study (Erdoğmuş, 2020), kindergarten teachers highlighted the need for training, materials, curriculum, infrastructure, and technical support specifically designed to facilitate the implementation of play with coding toys in kindergartens. In their study, Otterborn et al. (2019, p.259) found that teachers are 'aware of various skills, abilities and learning outcomes related to computational thinking, and aim to actively integrate these when developing and implementing programming activities'.

Notably few studies reported negative aspects from the teachers' perspective, although several recommendations did emerge with respect to training aimed at enhancing their confidence and appropriate preparation for the inclusion of coding toys in their ECEC teaching activities. This may be related to the manner in which the teachers were recruited as study participants—that is, as a self-selected sample or as volunteers (Bers et al., 2013; Erdoğmuş, 2020; Fridberg & Redfors, 2019, 2021; Fridberg et al., 2021; Otterborn et al., 2019; Palmér, 2017; Papadakis, 2022; Saxena et al., 2020; Wang & Wang, 2020); teachers willing to consent to the research activities (Lavigne et al., 2020) or, more specifically, to explore CT with children (Wang & Wang, 2020) or particularly interested in teaching programming (Heikkilä & Mannila, 2018; Ortega-Ruipérez & Lázaro Alcalde, 2022); or teachers with previous experience in coding activities (Hacıoğlu & Suiçmez, 2022) or committed to larger STEM projects (Shumway et al., 2021). Several articles do not clearly specify whether the teachers were volunteers but merely state that the sample was assembled via invitations issued by the research group (Bers et al., 2019). Five articles included no specifications as to how the teachers were recruited (Kewalramani et al., 2020; Lin et al., 2020; Liu et al., 2013; Nam et al., 2019; Sullivan & Bers, 2017)

RQ2: What pedagogical strategies do early childhood teachers use to support children' s in playing with coding toys in ECEC?

Of the 22 studies, 20 reported different pedagogical strategies adopted for the implementation of activities using coding toys in ECEC. We observed that the teachers' pedagogical approach involves different techniques. Two studies (Kewalramani et al., 2020; Wang et al., 2021) mentioned the employment of dialogic scaffolding to meet children's differential needs with respect to developing computational thinking, including targeted scaffolding that can be adjusted on an individual basis. The importance of visual support and communication through gestures is also presented (Erdoğmuş, 2020; Heikkilä & Mannila, 2018; Wang & Wang, 2020; Wang et al., 2021). Moreover, Lavigne et al. (2020) noted that teachers were able to engage children through targeted questions, particularly in debugging and algorithmic thinking, both of which are computational thinking skills, while teachers exhibited less confidence in supporting modularity skills, since they tended to simplify problems for the students rather than scaffolding the process. Using open questions, Palmér (2017) found that teachers sought to strike a balance between adult direction and children's initiative. Hacıoğlu and Suiçmez (2022) emphasised the importance of the teachers' questions in the children's communication, and group discussion emerged as crucial for engaging students in two studies (Bers et al., 2019; Sullivan & Bers, 2017). Bers et al. (2019) reported that the teachers working with the coding toys used and adapted the narrative to the children's development levels. Similarly, Liu et al. (2013) highlighted that asking questions can help students deal with problems that may arise in their use of programmable toys. Fridberg and Redfors (2019) observed that the teachers' approach involves scaffolded activities during the first phase, before the teachers move onto free enquiry and exploration through the children's ideas. Teachers coach these activities on both the individual and collaborative levels. Teachers' action in the form of scaffolding activities can enhance children's problem-solving skills and can help children to build trust in their own abilities (Otterborn et al., 2019). In another article, however, Fridberg and Redfors (2021) identified a way in which teachers might stimulate children through the implementation of a richer, more decontextualised language. Heikkilä and Mannila (2018) study also stressed the importance of using appropriate language and correct terminology to help children to properly conceptualise programming at an early age: in their study, the authors underlined that the teachers did not use programming terminology during the activities and that they likely required professional development, given that most of them lacked any previous programming background. Three studies mentioned the learning by doing approach (Erdoğmuş, 2020; Heikkilä & Mannila, 2018; Kewalramani et al., 2020), as an appropriate means of implementing robotic education and programming: 'In order for children to find their own errors and thereby practice, for instance, their logical thinking skills, teachers should not intervene "too soon" when they realise that a programme will not work. Programming is about "learning by doing", and making mistakes is an important part of this process' (Heikkilä & Mannila, 2018, p.17). Erdoğmuş (2020) identified two other approaches that teachers suggested were beneficial: teaching robotic education using games and demonstrative teaching. It is crucial that children be supported with concrete rules and guidance to foster their ability to play with coding toys (Liu et al., 2013), Where the children's learning was mediated through explicit instructions and scaffolding, it was done so in fun and meaningful ways (Wang et al., 2021).

Half of the studies analysed applied a combination of unplugged and plugged activities, and the unplugged activities were often reported as being implemented first. In particular, Otterborn et al. (2019) and Saxena et al. (2020) reported that the teachers clearly expressed their preferences for beginning with unplugged activities before moving on to plugged options. The teachers were broadly of the opinion that this approach equips children with more concrete programming experiences and helps them to gain greater confidence in applying those programming skills to plugged activities.

Two studies in particular clearly emphasised the teacher's role as that of a facilitator (Heikkilä & Mannila, 2018; Nam et al., 2019). More specifically, programming is regarded as a process wherein the children must be free to make mistakes so that they may learn from them (Heikkilä & Mannila, 2018). From this perspective, the teacher should assume the role of a facilitator by encouraging children to engage in activities that involve the use of coding toys (Nam et al., 2019) and trying not to intervene and correct the child too soon (Heikkilä & Mannila, 2018). Two studies (Shumway et al., 2021; Wang et al., 2021) reported that the teachers assumed a mediating role in children's learning using programmable toys by issuing clear instructions and scaffolding in a way that allows the activities to be simultaneously meaningful and fun.

The studies attest that various pedagogical strategies are used and that various possibilities exist with respect to incorporating the coding toys, delivering a pedagogy relevant to the context and possibly the technology. A detailed list of the different pedagogical strategies is reported in Appendix A.

RQ3: What detected or expected consequences have been identified with respect to children's skills development as a result of playing with coding toys?

To investigate the early childhood teachers' approaches and pedagogical methods with respect to the use of coding toys, we explored the corresponding skills in children where applicable. In so doing, we identified 18 studies that reported children's skills development. Fifteen studies detected such development, while three studies expected it. By 'detected', we mean that the studies identified a variation in the children's skills, while by 'expected', we refer to those studies that report the teachers' opinions about a possible children's skills development. Notably, of the 15 studies that detected these skills, 10 had adopted a qualitative approach; therefore, the variation in the skills was not identified using any quantitative instruments. Four of the remaining five studies applied mixed methods, and only one applied a quantitative method. The studies that expected (rather than detected) developments in the children's skills had implemented quantitative (two) and qualitative (one) methods. Nonetheless, those applying quantitative methods referred to data extracted from surveys with teachers.

Based on the included studies, we examined the various skills that children develop through the use of coding toys. We divided these results into two main categories: those that involve cognitive skills and those that involve socio-emotional skills. While cognitive skills are generally defined as mental abilities (Acosta et al., 2015), 'Social and emotional skills' refer to the abilities to regulate one's thoughts, emotions and behaviour. These skills differ from cognitive abilities such as literacy or numeracy because they mainly concern how people manage their emotions, perceive themselves and engage with others, rather than indicating their raw ability to process information '(OECD, 2017, p. 4).

With respect to the cognitive abilities mentioned in the included studies, problem-solving is among the most widely cited skills developed by the children, both detected in the activities and expected in the teachers' opinion (Erdoğmuş, 2020; Hacıoğlu & Suiçmez, 2022; Heikkilä & Mannila, 2018; Kewalramani et al., 2020; Liu et al., 2013; Nam et al., 2019; Otterborn et al., 2019). Five studies (Bers et al., 2019; Lin et al., 2020; Saxena et al., 2020; Sullivan & Bers, 2017; Wang et al., 2021) referred to children's increased interest and ability in coding and computational thinking, while five other studies showed that mathematical/STEM and computational thinking may develop mutually by leveraging one another (Fridberg & Redfors, 2021; Fridberg et al., 2021; Lavigne et al., 2020; Palmér, 2017; Sullivan & Bers, 2017).

Among the socio-emotional skills, collaboration and communication are most widely fostered through the implementation of coding activities: the children communicate and cooperate and are willing to share their ideas and reasoning, explain to one another and draw conclusions. (Bers et al., 2019; Fridberg & Redfors, 2021; Heikkilä & Mannila, 2018; Kewalramani et al., 2020; Liu & Iversen, 2022; Otterborn et al., 2019; Wang & Wang, 2020). Teachers also expect motivation as a potential consequence of robotic education (Erdoğmuş, 2020). Wang and Wang (2020) reported that the teachers were optimistic that using robots in computing education could stimulate six behaviours in the children: communication, collaboration, content creation, choice of conduct, creativity and community building. (Appendix B)

5 Discussion

Herein, we have presented a systematic literature review that aims to shed light on teachers' pedagogical strategies and views in supporting children's play with coding toys in ECEC while also examining which outputs are expected or detected in children's skills developed as a consequence of the activities. This contribution is particularly relevant in light of increasing research on the introduction of computational thinking to children at ECEC level -and filling the gap of the need to obtain a more profound understanding of the published literature with a focus on teachers' roles and provide state-of-the-art direction for the future. A total of 22 studies were included and analysed in detail.

Our findings attest that interest in the employment of coding toys in early childhood education is increasing, as the number of studies published has risen significantly within the last five years, with relatively high international representation. This result is in accordance with the growing consensus regarding the need to develop those 21st-century skills that are essential for children's futures (Grover & Pea, 2013) and the need to integrate coding into children's education as early as possible (Rich et al., 2019). Regarding the research methods used, most studies adopted a qualitative approach, and the main areas of interest are STEM and computational thinking.

Our systematic literature review confirms that teachers play an essential role in the application of coding toys in ECEC. In particular, teachers' views with respect to technology influence their implementation practices (Ertmer et al., 2012). It is thus essential to investigate their thoughts before considering their pedagogical approaches and methods. Overall, the results suggest that teachers generally have positive and constructive attitudes towards the use of coding toys and technology in the ECEC context. It is evident that a positive attitude towards educational technology, along with behavioural intentions to use such technology, ensures that pre-school teachers are more inclined to actually use it: the more engaged they are in integrating educational technology into their daily activities, the more likely it is that they will implement it in their educational environment (Rad et al., 2022). Regardless of whether teachers' approaches develop independently of their knowledge and experience, the need for proper training as an indispensable means of improving teachers' confidence is evident. Moreover, adequate training support teachers in building the competencies required to foster technology use among children in case of a lack of practical experience (Yang, 2022). Lack of confidence and lack of training are two of the main barriers that prevent teachers from integrating technology into their teaching (Jones, 2004).

Regarding the teachers' different pedagogical strategies, our results show that they use different scaffolding methods as a mediation based on dialogue, gestures and visual support. However, the dialogic scaffolding is the most applied. The concept of dialogic scaffolding may be referred to as 'dialogic teaching', a term coined by (Alexander, 2008), who defined dialogical teaching as a general pedagogical approach that capitalises on the power of conversation to foster students' thinking, learning and problem-solving. Therefore, dialogic exchanges are key for promoting deep learning, deeper thinking and communication skills in students of any age. In particular, play creates good opportunities for dialogic interactions (Salminen et al., 2021). An exploratory study published in June 2022 by Liu and Iversen (2022) found that the support offered through social dialogue between a six-year-old child and an adult (a parent, in this case) in experiences with tangible programming games has the potential to enhance a child's learning motivation, mitigate the game design's learnability problems and help improve the child's computational thinking skills.

Working with coding toys in ECEC also implies that teachers approach tasks in a playful learning manner, which is considered one of the most important sources of learning (Hirsh-Pasek et al., 2009). Thus, the use of coding toys may be regarded as a type of playful learning that paves the way for increased interest in the development of coding skills at ECEC level.

In terms of coding activities, we detected different combinations of plugged and unplugged activities, whereby the latter were considered essential for integrating and preparing children for plugged activities. Unplugged activities do not involve the use of digital devices. The literature offers evidence that the unplugged approaches also contribute to the development of computational thinking skills, although their effectiveness will inevitably decline at some point, and it is thus essential to use plugged activities (Brackmann et al., 2017).

The results also reveal that teachers serve as facilitators in activities using coding toys, supporting children in the coding process rather than simply issuing basic instructions. Nonetheless, it is their responsibility to help children to develop computational thinking skills, including the ability to think algorithmically, analyse ideas and break them up into different parts, trying to find issues or "bugs" (Yu & Roque, 2019). The results reveal how important it is that teachers are supportive and serve as mediators, mediating students' learning through coaching, facilitation, and scaffolding (Niu & Niemi, 2019).

As our results indicate, the use of coding toys is connected with computational thinking, considered one of the 21st-century skills (Haseski et al., 2018; Tabesh, 2017). computational thinking, with its phases of abstraction, decomposition, algorithmic design, evaluation, and generalisation (Selby & Woollard, 2013), is regarded as a problem-solving process (Maharani et al., 2019; Selby & Woollard, 2013; Voskoglou & Buckley, 2012), and ,in particular, it can be used in everyday life to train structured thinking for problem-solving (Andrian & Hikmawan, 2021). In the selected studies, problem-solving skills emerged as the most widely detected and cited output in the children's development after coding activities. Problem-solving skills are among those higher-order thinking skills that characterise 21st-century competencies (Brookhart, 2010). Our results also show a predominance of STEM, both in the areas of interest and as output in children's development when coding toys are involved. Coding activities can provide opportunities to support not only technologies and engineering, the two subjects more apparently associated with robotics, but also mathematics and science. All these subjects require the same skill—the ability to solve problems—and thus share some common ground with computational thinking. Therefore, coding toys serve as learning tools for understanding content (Ortega-Ruipérez & Lázaro Alcalde, 2022)—for example, mathematics and programming are valid subjects in and of themselves (Heikkilä & Mannila, 2018), but they are also beneficial tools for developing children's coding skills, given that problem-solving is necessary for moving and programming the robots' tasks (Papadakis, 2022). Using coding toys, children can develop a set of indispensable skills to support them as they negotiate unfamiliar and evolving conditions. These skills are identified by the OECD Learning Compass 2030 (OECD, 2018), and they include not only cognitive and meta-cognitive skills such as critical thinking, creative thinking, learning to learn and self-regulation, but also social and emotional skills such as empathy, self-efficacy and collaboration. Moreover, they include practical and physical skills, such as using new information and communication technology devices.

It has not been easy or even possible to identify precise patterns in terms of direct correspondence of pedagogical strategies with output in children's development. We can see from the data that the questioning techniques, as the most widely applied scaffolding practice, involve different types of outputs, particularly where the focus is on the development of mathematics (STEM) skills, computational thinking skills and, more directly, problem-solving skills. We also identified dialogic scaffolding as involved in the development of most socio-emotional skills, including communication and collaboration.

6 Conclusions and Future Work

This systematic review aimed to identify the pedagogical strategies that early childhood education teachers employ when using coding toys or related activities in the classroom. In doing so, we also examined teachers' views as well as the outcomes with respect to children's development. To this end, we searched four different databases using appropriate keywords and inclusion/exclusion criteria. This process afforded us a sample of 22 articles relevant to this scope.

The results of the analysis confirm the recent increase in attention to the implementation of coding toys as early as kindergarten. This awareness is relatively widespread globally, with broad consensus about the importance of working in early childhood education with coding activities that foster the development of children's computational skills, which are—together and in close connection with problem-solving, critical thinking, and multiple higher-order thinking skills—considered integral to the essential 21st-century skill set.

However, the low number of studies that were suitable for inclusion highlights the relatively minor focus on teachers. Our analysis indicates both a positive approach to technology in general and to coding activities, regardless of the teachers' previous knowledge or experiences. Nonetheless, the need for proper teacher training that will allow teachers to adopt the optimal approach to technology emerged clearly from the articles. Among the various scaffolding approaches adopted, dialogic scaffolding was the most widely applied by teachers, who typically assume the role of facilitator in their mediation activities as they supervise children's use of coding toys. The use of unplugged activities can help teachers introduce coding toys to children. In all 22 studies, the implementation of coding toys in tandem with proper teacher scaffolding yielded positive results. Owing to the teachers' essential role in implementing coding toys in early education, future research should focus on their role and needs in various aspects—for example, which pedagogies are most appropriate for application with the technology in terms of maximising the pedagogical benefits of the children and, not least, the training that the teachers will require not only in-service but also during the pre-service stage and at the university courses level.

The present systematic literature review is part of a research project, and the results will be used, together with the results from a set of observations, to identify leading practical approaches in ECEC teachers' professional digital competence. This study will be a starting point for investigating good pedagogical practices for coding toys in early childhood education. We hope that it will help researchers to refine the methods and approaches available to ECEC teachers implementing coding toys and to designing and developing suitable research-based resources to assist teachers in enriching and supporting children's play with coding toys.

7 Limitations

First, we cannot claim to have included all relevant studies in the existing literature; this systematic literature review used the rigorous methodology described above and included only relevant studies based on the inclusion of articles obtained through particular search terms across a selection of databases. Different search terms and methodologies could have yielded different results. Moreover, our analysis of the collected studies was focused on specific areas that related to our research questions; again, we acknowledge that application of another strategy may have produced different outcomes. Moreover, the inclusion of papers in the English language exclusively may be a source of possible bias. In terms of results, the teachers' positive approach may be affected by the method by which the teachers were recruited for participation, since, in 8 studies, the teachers volunteered to join the projects. For the other 14, it was not specified whether the participants had the free will to participate in the various studies. Therefore, studies for which the recruitment process also involves participants who are unwilling to work with coding toys, programming, coding or computational thinking are warranted.

Data availability statement

Data sharing not applicable to this article as no datasets were generated or analysed during the current study. Information about the references and information for the studies analysed are in Apendix A,B,C.

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PLAY WITH CODING TOYS IN EARLY CHILDHOOD EDUCATION AND CARE

Appendix A

Sources	Type of activities	Materials (tangible and/or digital)	Didactic approaches	Pedagogical strategies
Bers et al., 2013	Plugged	Interlocking wooden blocks, KIWI with CHERP, programming software, Lego WeDO	Technology is integrated with other subjects (social studies, culture, history).	The teachers adapt their activities to the classroom and the students. Teachers enhance children's cooperation and group discussion.
Bers et al., 2019	Plugged	Kibo robot kit	Technology is integrated with other subjects (geometrical shapes, numbers, reading vowels). Gamifying strategies and narratives and storytelling, songs, dances and games are used.	The teachers adapt the curriculum to the needs of the class. The teachers engaged their students through group discussions. The teachers also adapted the narrative used to the children's level of development, presenting the concepts, behaviors and skills required of them in an orderly and continuous progression.
Wang et al., 2021	Plugged	Code-a-pillar	Storytelling is used.	The teachers adapt the activity to the group and prepare reachable goals. Teachers and children use language and gestures. Teachers use verbal scaffolding. Teachers encourage children to communicate and collaborate with each other. Teachers support children's independence and creativity in evaluating and choosing a strategy and have a positive attitude toward errors.

PLAY WITH CODING TOYS IN EARLY CHILDHOOD EDUCATION AND CARE

Sources	Type of activities	Materials (tangible and/or digital)	Didactic approaches	Pedagogical strategies
Fridberg and Redfords, 2021	Plugged and unplugged	Blue Bot	Activities are related to reality. Plugged activities: programming activities for moving the robot through a path. Information is obtained from cards before that show the movement, then the robot has to move on the grid. Unplugged activities: children program each other for following a path, putting arrows on the floor.	The teachers use decontextualized language.
Fridberg et al., 2021	Plugged and unplugged	Blue Bot	Plugged activities: programming activities for moving the robot through a path. Unplugged activities: children program each other for following a path, putting arrows on the floor.	The teachers adapt the activities to the group of children. Teachers support children in developing their own discovery and experience. Teachers relate the activity to a STEM content.
Kewalramani et al., 2019	Plugged	LittleBits	Activities are based on a child-centred approach: inquiry processes are driven by the children in order to build objects for their robot city.	Teachers lead the children in evaluating the situations through questions. Teachers support children's inquiry skills through open-ended questions. Teachers give targeted feedback.
Lavigne et al., 2020	Plugged and unplugged	Cards, animal shapes, bracelets, apps	Activities are hands-on, built in order to support children's computational thinking.	Teachers use questions to support children's understanding. Teachers broke simplifies the activities. Teachers support children in generating ideas about how to solve a problem. Teachers support children in developing their own strategy.

PLAY WITH CODING TOYS IN EARLY CHILDHOOD EDUCATION AND CARE

Sources	Type of activities	Materials (tangible and/or digital)	Didactic approaches	Pedagogical strategies
Liu, 2013	Plugged	Topobo programmable bricks	The activity is a treasure hunting map.	The teachers provide guidance and explain the task. The teachers correct the mistakes asking question to the children in order to support their own evaluation. The teachers encourage children to share new ideas.
Otterborn et al., 2020	Plugged and unplugged	Blue-Bot, Bee-Bot, ScratchJr, Scottie Go, Go for Dash, Code carts, A.L.E.X (divided in programming directly on the digital tablet screen using various appls and programming with help of tangible manipulatives robots.	The activities are integrated with multiple content areas such as project work, and linked to various conceptual domains (science, technology, mathematics, language).	The teachers present unplugged activities before the plugged activities, for helping the children in understanding the different part of the programming process. Teachers help the children in having concrete experiences with programming. Teachers support cooperation among children. Teachers support children's own ability and self esteem in solving the problems.
Palmer, 2017	Plugged and unplugged	Bee-Bot	The activities are integrated in the ordinary pre-school activities. Activities are based on children's free will and curiosity. The activities are built for allowing children to use mathematics for investigating different solutions. Plugged activities are based on programming a robot on a grid or a map, receiving a code, guessing where the robot can	The teachers give guided interaction. Teachers have both a reactive and a proactive role. Teachers ask open questions to the children. Teachers support child's initiatives and dialogues. The teachers plan the activities but are open to children suggestions.

PLAY WITH CODING TOYS IN EARLY CHILDHOOD EDUCATION AND CARE

Sources	Type of activities	Materials (tangible and/or digital)	Didactic approaches	Pedagogical strategies
			go and then trying it out programming the robot and observing it. Unplugged activities are activities where a child is programmed through arrows on paper.	
Sullivan and Bers, 2017	Plugged	Wooden programming blocks, different material for customizing KIBO robots	The coding activities are integrated with other subjects (arts and crafts, music, dance)	Activities are presented to the children by the teachers. Teachers adapt the curriculum to the group of children. Teachers can adapt the activities to children's culture. The teachers devide the activity is smaller parts.
Erdogmus, 2021	-	-	Activities should be based on games. Activities should include visual and tangible materials. Activities should be related to STEM and reality.	Teachers should support children independence and creativity. Teachers should support brainstorming. The teachers should present an activity from a simple perspective to a more complex one.
Wang, 2020	Plugged	Keeko robot	The activities should be conducted in small group.	Teachers create an interactive environment. Teachers create a more flexible teaching process.

PLAY WITH CODING TOYS IN EARLY CHILDHOOD EDUCATION AND CARE

Sources	Type of activities	Materials (tangible and/or digital)	Didactic approaches	Pedagogical strategies
Heikkila & Mannila, 2018	Plugged and unplugged	Blue-Bot and Ipads	Unplugged: programming using verbal instructions or cards (Lego blocks, magnets, musical instruments, cards with given pictures, as arrows cards) Plugged: blue bot and ipad	Teachers communicate in a multimodal approach (verbal language, gestures, gaze, …) The teachers support children in developing their own problem solving skill. The teachers support the negotiations among the children. The teachers support children's reasoning about the errors.
Fridberg and Redfords, 2019	Plugged and unplugged	Blue-Bot and different materials	Plugged: Using Blue Bot as a link between different aspects of a natural science phenomenon (children have to program the robot for moving it between two pictures that are connected because related to the same phenomenon) Unplugged: using a child as a Blue Bot	Different coaching strategies are used, independently from the activities being plugged or unplugged. The teachers establish a common ground of understanding. Teachers support children's own inquiry and exploration.
Saxsena et al., 2020	Plugged and Unplugged	LEGO pattern, vocabulary building songs, direction game through cards, Tic-Tac-Toe, Bee-Bot	Plugged: Bee Bot Unplugged: Lego pattern (pattern building activity for enhancing pattern recognition skills. Children have to recognize and to continue patterns), sequencing stories (pictures representing different moments of a story have to be	Teachers support children's learning by giving them instructions before and during the activities.

PLAY WITH CODING TOYS IN EARLY CHILDHOOD EDUCATION AND CARE

Sources	Type of activities	Materials (tangible and/or digital)	Didactic approaches	Pedagogical strategies
			put in correct sequence, for example 6 pictures of a daily rutine), vocabulary building songs (nursery rithm are payed and children have to follow and act as the song is saying), direction game through cards (a child move a caterpillar or a doll and the teacher or another child gives instruction through card with arrows for moving it from a position to another), Tic-tac-toe (a child acts as a robot, and the teacher or another child gives verbal command in order to move from a position to another)	
Nam et al., 2019	Plugged and Unplugged	Turtle Bot	The children receive a challenge. Then they use before pens and stickers wor drowing a possible path on a worksheet. They controlled that with the teacher and among them. Then They tried out with the robot.	The role of teachers as a facilitator is an important part of encouraging and providing scaffolds to engage kindergartners in robotics activities properly. The teachers ask question for helping the children to reflect on a possible wrong solution

PLAY WITH CODING TOYS IN EARLY CHILDHOOD EDUCATION AND CARE

Sources	Type of activities	Materials (tangible and/or digital)	Didactic approaches	Pedagogical strategies
Lin et al., 2020	Plugged	Colour labelled cards, tangible user interface, Arduino-based robot cars	The children combines coloured cards of A4-size and 10 x 10 answer cards for preparing a program. Arduino robot reads the program.	The teachers use dialogue for supporting children's learning. The teachers encourage the children in expressing their ideas. The teachers let the children play freely, and help them when they encounter a difficulty. The teachers ask open questions.
Hacioglu & SUicmez, 2022	Plugged and unplugged	Bee Bot	Unplugged: to build a tactile path with paper, cardboard, corrugated cardboard, eva, felt, coloured pencils, crayons, sketch mat, coding mat, various adhesives/glue Plugged: Bee-Bot Coding Robots Problem related to the real world	The teacher plans accurately the activity, and presents it to the children. The teacher observe children's learning and contribute to it giving them appropriate material, supporting their discussion, suggesting to reflect about possible improvements. The teachers "serves as a secret guide"
Shumway et al., 2021	Plugged and unplugged	Botley Cubetto	Unplugged (realized before the plugged): sequencing going on a Bear Hunt, programming each other to move in theri classrooms, board games. Plugged: Activities for programming in order to move the robot from a position to another. The activity is built in	The teachers have a mediation role. The teacher became a part of a semiotic chain in students' conversations as they negotiated the meaning of these signs

PLAY WITH CODING TOYS IN EARLY CHILDHOOD EDUCATION AND CARE

Sources	Type of activities	Materials (tangible and/or digital)	Didactic approaches	Pedagogical strategies
			order to lead the children to producing signs	

PLAY WITH CODING TOYS IN EARLY CHILDHOOD EDUCATION AND CARE

Appendix B

Sources	Detected or expected skills	Teachers' pedagogical strategies	Cognitive skills	Socio-emotional skills
Bers et al. (2019)	Detected skills	The teachers adapted the curriculum to the needs of the class. The teachers engaged their students through group discussions. The teachers also adapted the narrative used to the children's level of development, presenting the concepts, behaviors and skills required of them in an orderly and continuous progression.	Children achieved a high level of mastery of coding and computational thinking skills using robotics.	The intervention was successful in fostering communication and collaboration. At the same time, its effect on promoting content creation and creativity was moderate and low in terms of promoting conduct choices and community building.
Wang et al. (2021)	Detected skills	The teachers adapted the activity to the group and prepared reachable goals. Teachers and children use language and gestures. Teachers used verbal scaffolding. Teachers encouraged children to communicate and collaborate. Teachers supported children's independence and creativity in evaluating and choosing a strategy and have a positive attitude toward the errors.	The study illustrates preschoolers' ability to engage in difficult CT practices and perspectives.	
Fridberg and Redfors (2021)	Detected skills	The teachers used a richer, more decontextualised language	When the teachers use richer, more decontextualised language, this seems to stimulate the children to express more statements in the different Bers' and STEM categories.	

Sources	Detected or expected skills	Teachers' pedagogical strategies	Cognitive skills	Socio-emotional skills
Fridberg et al. (2021)	Detected skills	The teachers adapted the activities to the group of children. Teachers supported children in developing their own discovery and experience. Teachers related the activity to a STEM content.	Children's interest in STEM has increased, and Children's understanding in STEM has increased. Children's understanding in robotics has increased. Robotics supports children with special needs. Robotics supports children's agency.	Robotics supports children's interactions with each other.
Kewalramani et al. (2020)	Detected skills	Teachers led the children in evaluating the situations through questions. Teachers supported children's inquiry skills through open-ended questions. Teachers gave targeted feedback.	This study further contributes to work in the field of STEM-focused learning in the early years using IoToys/robotic toys where children are seen as being capable of demonstrating intelligent behavior indicators such as creative collaboration, procedural thinking, resilience, and adapting strategies to overcome failure.	
Lavigne et al. (2020)	Detected skills	Teachers used questions to support children's understanding. Teachers broke simplifies the activities. Teachers supported children in generating ideas about how to solve a problem. Teachers supported children in developing their own strategy. Through teachers' targeted questions, they were able to identify problems and then take steps to create solutions eventually.	Through a combination of hands-on activities and digital apps, teachers can generate meaningful experiences for pre-school children to explore CT by leveraging their existing mathematical knowledge.	

Sources	Detected or expected skills	Teachers' pedagogical strategies	Cognitive skills	Socio-emotional skills
Liu et al. (2013)	Detected skills	The teachers provided guidance and explained the task. The teachers corrected the mistakes by asking the children questions to support their own evaluation. The teachers encouraged children to share new ideas.	The child developed assembling ability, a willingness to share his ideas, and the ability to identify and solve problems.	Willingness to share his ideas
Otterborn et al. (2020)	Expected skills	The teachers presented unplugged activities before the plugged ones to help the children understand the different parts of the programming process. Teachers helped the children in having concrete experiences with programming. Teachers supported cooperation among children. Teachers supported children's own ability and self-esteem in solving problems.	Cooperation with one-another, scaffolding children's (creative) problem-solving and building trust in children's own ability is very much at the forefront of pre-school teachers' integration of programming activities.	Cooperation with one-another, (creative) problem-solving
Palmér (2017)	Detected skills	The teachers gave guided interaction. Teachers have both a reactive and a proactive role. Teachers asked open questions to the children. Teachers supported child's initiatives and dialogues. The teachers planned the activities but were open to the children's suggestions.	The results indicate that the children developed their ability to mentally compare and connect movements in reality with maps and symbols. Further, the children showed the ability to mentally envision, hold in mind, and conceptualise actions and relationships between paper maps, gridded maps, and symbols. Thus, the intervention	

PLAY WITH CODING TOYS IN EARLY CHILDHOOD EDUCATION AND CARE

Sources	Detected or expected skills	Teachers' pedagogical strategies	Cognitive skills	Socio-emotional skills
			indicates potential in teaching mathematics through programming in pre-school.	
Sullivan and Bers (2017)	Detected skills	Activities are presented to the children by the teachers. Teachers adapted the curriculum to the group of children. Teachers can adapt the activities to children's culture. The teachers divided the activity is smaller parts.	Results indicate that children were highly successful at mastering foundational programming concepts.	
(Erdoğmuş, 2020)	Expected skills	Teachers should support children's independence and creativity. Teachers should support brainstorming. The teachers should present an activity from a simple perspective to a more complex one.	Nine participants stated that robotic education in kindergarten could help develop some thinking skills. These thinking skills were problem-solving, reasoning, practical thinking, algorithmic thinking, creative thinking, critical thinking, and sorting. Five participants stated that robotic education could teach and increase children's problem-solving skills.	The second theme that emerged in this study showed that ECE teachers thought there would be many advantages of robotic education for children. Among these advantages, motivation was the most emphasised possible positive effect of robotic education.
Wang and Wang (2020)	Expected skills	Teachers created an interactive environment. Teachers created a more flexible teaching process.		Using Keeko robots in computing education can stimulate children's six behaviours, including communication (Com), collaboration (Col), content creation (Con.C), choice of conduct (Cho.C), creativity (Cre), community building (Com.B).

PLAY WITH CODING TOYS IN EARLY CHILDHOOD EDUCATION AND CARE

Sources	Detected or expected skills	Teachers' pedagogical strategies	Cognitive skills	Socio-emotional skills
Heikkilä and Mannila (2018)	Detected skills	Teachers communicated in a multimodal approach (verbal language, gestures, gaze, ...) The teachers supported children in developing their own problem-solving skill. The teachers supported the negotiations among the children. The teachers supported children's reasoning about the errors.	Programming in pre-school can be seen as focusing on playful learning, where children can use their imagination while developing their problem-solving skills.	The children in our study showed interest in the programming activities and exhibited both patience and willingness to follow the teacher's instructions. This is in line with previous research, which found the pre-school children often find programming activities attractive and engaging and something they explore in a playful and curious manner. The children also communicate and cooperate when solving different problems together; they explain their reasoning to each other and draw conclusions.
(Fridberg & Redfors, 2019)		Different coaching strategies were used, independently from the plugged or unplugged activities. The teachers established a common ground of understanding. Teachers support children's own inquiry and exploration.		
Saxena et al. (2020)	Detected skills	Teachers supported children's learning by giving them instructions before and during the activities.	We found that the K2 (aged 4 to 5) and K3 (aged 5 to 6) students could generally demonstrate their ability of pattern recognition, sequencing, and algorithm design. By contrast, the K1	

Sources	Detected or expected skills	Teachers' pedagogical strategies	Cognitive skills	Socio-emotional skills
			students failed to design a correct algorithm in some complicated problems.	
Nam et al. (2019)	Detected skills	The role of teachers as facilitators is an important part of encouraging and providing scaffolds to properly engage kindergartners in robotics activities. The teachers asked questions to help the children to reflect on a possible wrong solution.	The findings from the present study suggest that kindergarteners can enhance their problem-solving and planning abilities through a robotics curriculum. The results of this study demonstrate that children who experienced the instruction model and curriculum using the card-coded robot were more proficient in arranging pictures into a predetermined sequence (sequencing) and solving mathematical problems (problem-solving). Therefore, engaging in card-coded programming seems to benefit children because it allows them to elaborate on their experiences and to create and execute plans to solve problems The card-coded robotic activities, which included worksheets as a complementary tool and hands-on activities involving physical computational objects, can make abstract concepts or symbolic representations more accessible	

Sources	Detected or expected skills	Teachers' pedagogical strategies	Cognitive skills	Socio-emotional skills
			to children (Antle 2013a; Resnick 2006) by supporting the demonstration of physical actions on computational objects, thereby facilitating problem-solving at the children's current level of cognitive capacity.	
Lin et al. (2020)	Detected skills	The teachers used dialogue to support children's learning. The teachers encouraged the children to express their ideas. The teachers let the children play freely and help them when they encounter difficulties. The teachers ask open questions.	The results suggest using the developed game-based TUI system (Tangible User Interface) can increase pre-school children's learning behaviours as well as enhance their learning interests and computational thinking abilities.	Increase pre-school children's learning behaviours
Hacıoğlu and Suiçmez (2022)	Detected skills	The teacher accurately planned the activity and presented it to the children. The teacher observed and contributed to the children's learning by giving them appropriate material, supporting their discussion, and suggesting to reflect on possible improvements. The teachers "serves as a secret guide"	This study shows that children can operate, design, and test the engineering design process at a simple level to solve complex interdisciplinary problems. It also shows that when children learn robotic programming in early childhood - without any computer screen, just Bee-Bot - they can apply it to real-world situations. It is also an indication that art activities that allow them	

PLAY WITH CODING TOYS IN EARLY CHILDHOOD EDUCATION AND CARE

Sources	Detected or expected skills	Teachers' pedagogical strategies	Cognitive skills	Socio-emotional skills
			to use their creativity more can be integrated into this	
Shumway et al. (2021)	Detected skills	The teachers had a mediation role. The teacher became a part of a semiotic chain in students' conversations as they negotiated the meaning of these signs	We found that kindergarten children used spatial, measurement, and number knowledge, and the design of the tasks, affordances of the robots, and types of programming knowledge influenced how the students engaged with mathematics. Students engaged in dynamic and interconnected mathematics, a deviation from traditional school mathematics which tends to focus on static notions of mathematics and individual skills that are later connected.	

PLAY WITH CODING TOYS IN EARLY CHILDHOOD EDUCATION AND CARE

Appendix C

No of paper	Author(s), publication year, country	Sample size of teachers	Sample size of children	Metho dology	Instruments	Duration of study (and/or duration of children's interaction)	Data analysis	Training (before implementing a specific activity)	Types of activities	Materials (tangible and/or digital)
1.	Bers et al., 2013 USA	32 participants (final sample 25)	-	mixed	pre and post online survey, semistructured interviews	3 days	t-test	-	plugged	interlocking wooden blocks, KIWI with CHERP programming software, LEGO WeDO
2.	Bers et al., 2019 Spain	16	172	mixed	questionnaires and PTD check list, observations, interviews, diary journal, focus group	5 months (3 to 5 sessions of 45 mins or 1h 15 mins)	categories and coding	one-day face-to-face training session	plugged	KIBO robot kit
3.	Wang et al., 2021 USA	1 exemplary ECEC educator	3	qualita tive	Video recordings	12 weeks (12 sessions of 20 mins)	open and a priori coding	-	plugged	Code-a-pillar (a programmable toy)
4.	Fridberg and Redfors, 2021 Sweden	5 pre-school teachers	16	qualita tive	Observations video recorded	part of 3 years project (110 mins)	content-based analysis	previously involved in professional development courses	plugged and unplugge d	Blue bot

PLAY WITH CODING TOYS IN EARLY CHILDHOOD EDUCATION AND CARE

No of paper	Author(s), publication year, country	Sample size of teachers	Sample size of children	Metho dology	Instruments	Duration of study (and/or duration of children's interaction)	Data analysis	Training (before implementing a specific activity)	Types of activities	Materials (tangible and/or digital)
5.	Fridberg et al., 2021 Spain and Sweden	10 pre-school teachers (Sweden) 11 pre-school teachers (Spain)	5 (Sweden) 3 (Spain)	mixed	Questionnaire, focus group interviews	part of 3 years project	creation of categories	an introductory meeting	plugged and unplugged	Blue bot
6.	Kewalramani et al., 2019 Australia	3	17	qualitative	observations	4 weeks, 8+ weeks (10h)	descriptive	-	plugged	LittleBits
7.	Lavigne et al., 2020 USA	11 (study A)	28 (study A) 25 (study B)	qualitative	observations video recorded	-	coding process	workshop for CT	hands-on activities on digital apps	cards, shapes, bracelets
8.	Liu, 2013 Taiwain	1	1	qualitative	observations, videotaped teaching case	(4 h course)	content analysis		plugged	Topobo programmable bricks

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9.	Ortega and Alcalde,2022 Spain	38	-	quantitative	questionnaire	-	descriptive, ANOVA	-	-	-
10.	Otterborn et al., 2020 Sweeden	199	-	quantitative	survey	-	Tabulated and quantified terms, thematic content analysis	-	-	Blue-Bot, Bee-Bot, ScratchJr, Scottie Go, Go for Dash, Code carts, A.L.E.X
11.	Palmer, 2017 Sweeden	3	8	qualitative	observations	4 months	-	-	plugged and unplugged	Bee-Bot
12.	Papadakis, 2022 Greece	97	-	quantitative	questionnaire	-	descriptive	-	-	Educational robotics in general
13.	Sullivan and Bers, 2017 Singapore	5	98	mixed	interviews, journals, scores on student assessments	Min 5 or 8+ sessions of 1 hour (once a week for 1h)	descriptive, themes extraction	1-day training	plugged	Wooden programming blocks, different material for customizing KIBO robots

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14.	Erdoğmuş, 2021 Turkey	10	-	qualita tive	Semi-structured and in depth-interviews	-	content analysis	-	-	-
15.	Wang, 2020 China	89	-	quantit ative	questionnaire	8-16 weeks	single-sample Wilcoxon signed-rank test	demonstration course	plugged	Keeko robot
16.	Heikkila &Mannila, 2018 Finland	2	-	qualita tive	video recordings	(25 programming sessions)	themes/categ ories	-	plugged and unplugge d	Bluebots and iPads
17.	Fridberg and Redfors, 2019 Sweeden	2	10	qualita tive	video recordings	27min and 30min	identification of categories	introductory meeting	plugged and unplugge d	different materials in unplugged activities, Blue-bot
18.	Saxsena et al., 2020 Hong Kong	6	11	qualita tive	performance assessments, observations, interviews	1 week +2 hours (10h)	rubric of performance assessment, thematic analysis	2-h workshop	plugged and unplugge d	LEGO pattern, vocabulary building songs, direction game through cards, Tic-Tac-Toe, Bee-Bot

PLAY WITH CODING TOYS IN EARLY CHILDHOOD EDUCATION AND CARE

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19.	Nam et al., 2019 Korea	2	53	quantit ative	pre-post tests	8 weeks	descriptive, ANCOVA	-	plugged and unplugge d	TurtleBot
20.	Lin et al., 2020 Taiwan	-	7	mixed	questionnaires, video observations	20mins lesson 20min questions	-	-	plugged	Colour labelled cards, tangible user interface, Arduino-based robot cars
21.	Hacıoğlu & Suiçmez, 2022 Turkey	1	20	qualita tive	field notes	5 days	descriptive	-	plugged and unplugge d	paper, cardboard, corrugated cardboard, eva, felt, coloured pencils, crayons, sketch mat, coding mat, Bee-Bot Coding Robots, various adhesives/glue
22.	Shumway et al., 2021 USA	2	36	qualita tive	video recordings	10 weeks (8h)	provision and thematic coding	The students (children) had previously engaged in unplugged activities	plugged and unplugge d	Botley - Cubetto

PLAY WITH CODING TOYS IN EARLY CHILDHOOD EDUCATION AND CARE

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Appendix 4 – NSD (Sikt) Approval

Sikt

Notification form / Høyere ordens tenkning i barnehagen / Assessment

Assessment of processing of personal data

Reference number	Assessment type	Date
258279	Standard	17.03.2023

Project title
Høyere ordens tenkning i barnehagen

Data controller (institution responsible for the project)
Universitetet i Stavanger / Fakultet for utdanningsvitenskap og humaniora / Nasjonalt senter for læringsmiljø og atferdsforsking

Project leader
Enrico Pollarolo

Project period
12.10.2020 - 31.12.2023

Categories of personal data
General

Legal basis
Consent (General Data Protection Regulation art. 6 nr. 1 a)

The processing of personal data is lawful, so long as it is carried out as stated in the notification form. The legal basis is valid until 31.12.2023.

Notification Form

Comment
Personverntjenester har vurdert endringen i prosjektsluttdato.

Vi har nå registrert 31.12.2023 som ny sluttdato for behandling av personopplysninger.

Vi vil følge opp ved ny planlagt avslutning for å avklare om behandlingen av personopplysningene er avsluttet.

Kontaktperson: Marita Helleland
Lykke til videre med prosjektet!

Appendix 5 – Information letter

Vil du delta i forskningsprosjektet

«Høyere ordens tenkning i barnehagen»

Dette er et spørsmål til deg om å delta i et forskningsprosjekt hvor formålet er å utforske betydningen av høyere ordens tenking i barnehagen, med fokus på forholdet mellom matematikk og barns utvikling av høyere ordens tenkning. Enkelt forklart består høyere ordens tenkning av evnen til å overføre det man lært i en situasjon til en annen, evnen til kritisk tenkning, og evnen til problemløsning. I dette skrivet gir vi deg informasjon om målene for prosjektet og hva deltakelse vil innebære for deg.

Formål

Prosjektet tar sikte på å utforske pedagogiske praksiser i barnehager i Norge og Italia med fokus på forholdet mellom matematikk og barns høyere ordens tenkning. Vi er interessert i å studere barnehagelæreres erfaringer fordi lærere spiller en nøkkelrolle i å støtte utvikling av høyere ordens tenkning hos barn. Prosjektet vil studere sammenhengen mellom nasjonale læreplaner og læreres perspektiv på høyordens tenkning og matematikk, spesielt om det er samsvar mellom nasjonale læreplaner og læreres oppfatning av potensialet i høyere ordens tenkning og matematikk hos barn i barnehagen.

Hvem er ansvarlig for forskningsprosjektet?

Universitetet I stavanger er behandlingsansvarlig institusjon. Nasjonalt senter for læringsmiljø og atferdsforskning og Filiorum er ansvarlig for prosjektet. Prosjektet er en del av en doktorgradsavhandling, der Enrico Pollarolo er prosjektansvarlig, veiledet av professor Natalia Kucirkova og professor Ingunn Størksen

Hvorfor får du spørsmål om å delta?

Deltakerne i dette prosjektet er barnehagelærere i Stavanger-regionen.

Hva innebærer det for deg å delta?

Hvis du velger å delta i prosjektet, innebærer det at du deltar i et intervju. Intervjuet tar maksimalt 45 minutter. Intervjuet vil fokusere på din mening om barns høyere ordens tenkning og matematikk. Dine svar blir registrert elektronisk. Jeg tar lydopptak og notater fra intervjuet.

Det er frivillig å delta

Det er frivillig å delta i prosjektet. Hvis du velger å delta, kan du når som helst trekke samtykket tilbake uten å oppgi noen grunn. Alle dine personopplysninger vil da bli slettet. Det vil ikke ha noen negative konsekvenser for deg hvis du ikke vil delta eller senere velger å trekke deg.

Ditt personvern – hvordan vi oppbevarer og bruker dine opplysninger

Vi vil bare bruke opplysningene om deg til formålene vi har fortalt om i dette skrivet. Vi behandler opplysningene konfidensielt og i samsvar med personvernregelverket.
Enrico Pollarolo vil samle inn, bearbeide, lagre data. En annen forsker vil delta på intervjuet som assistent. Denne forskeren vil derfor ha tilgang til data og vil hjelpe med transkribering ved behov. Det vil ikke være andre personer ved andre institusjoner som skal ha tilgang på datamaterialet fra denne studien. I all publikasjon knyttet til prosjektet vil datamaterialet anonymiseres. Ved behandlingsansvarlig institusjon vil prosjektansvarlige, professor Natalia Kucirkova og professor Ingunn Størksen ha tilgang på datamaterialet. Det bli laget en koblingsnøkkel, som gjør at navnet og kontaktopplysningene dine blir erstattet med en kode i datamaterialet. Koblingsnøkkelen lagres på en egen sikker server – der kun forskningsadministrasjonen har tilgang.

Hva skjer med opplysningene dine når vi avslutter forskningsprosjektet?
Opplysningene anonymiseres når prosjektet avsluttes/oppgaven er godkjent, noe som etter planen er 28.02.2023. Alle personopplysninger og opptak vil bli slettet ved prosjektslutt.

Dine rettigheter
Så lenge du kan identifiseres i datamaterialet, har du rett til:
- innsyn i hvilke personopplysninger som er registrert om deg, og å få utlevert en kopi av opplysningene,
- å få rettet personopplysninger om deg,
- å få slettet personopplysninger om deg, og
- å sende klage til Datatilsynet om behandlingen av dine personopplysninger.

Hva gir oss rett til å behandle personopplysninger om deg?
Vi behandler opplysninger om deg basert på ditt samtykke.

På oppdrag fra Læringsmiljøsenteret (Nasjonalt senter for læringsmiljø og atferdsforskning) har NSD – Norsk senter for forskningsdata AS vurdert at behandlingen av personopplysninger i dette prosjektet er i samsvar med personvernregelverket.

Hvor kan jeg finne ut mer?
Hvis du har spørsmål til studien, eller ønsker å benytte deg av dine rettigheter, ta kontakt med en av følgende personer:
- Enrico Pollarolo ved Nasjonalt senter for læringsmiljø og atferdsforskning, epost: enrico.pollarolo@uis.no
- Natalia Kucirkova, ved Nasjonalt senter for læringsmiljø og atferdsforskning, epost: natalia.kucirkova@uis.no
- Vårt personvernombud: personvernombud@uis.no.

Hvis du har spørsmål knyttet til NSD sin vurdering av prosjektet, kan du ta kontakt med:
- NSD – Norsk senter for forskningsdata AS på epost (personverntjenester@nsd.no) eller på telefon: 55 58 21 17.

Med vennlig hilsen

E Pollarolo

(Forsker) (Veileder)

Samtykkeerklæring

Jeg har mottatt og forstått informasjon om prosjektet «Høyere ordens tenkning i barnehageopplaring», og har fått anledning til å stille spørsmål. Jeg samtykker til:

☐ å delta i intervju

(Navn)

(Arbeidssted og stilling)

(Telefon)

(Mail)

Jeg samtykker til at mine opplysninger behandles frem til prosjektet er avsluttet

---
(Signert av prosjektdeltaker, dato)

Vennligst returner dette skjemaet til:

(barnehagelærernes navn)