



Meta-thematic synthesis of research on early childhood coding education: A comprehensive review

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Abstract

The growing significance of coding in 21st-century early childhood education extends beyond technical proficiency, encompassing cognitive development, problem-solving, and creativity. Coding is being integrated globally into educational curricula to prepare students for the digital era. This research examines coding's potential impact on cognitive and socio-emotional development and emphasizes the need for evidence-based analysis. A meta-thematic analysis synthesizes qualitative data from various studies in a study on coding's effects on preschool children's cognitive and socio-emotional development. It focuses on two themes: cognitive contributions and socio-emotional contributions. Thirteen suitable studies were identified from 942 visualized using the PRISMA flow diagram. Coding education enhances cognitive and socio-emotional skills in preschoolers, with implications for curriculum integration. In summary, coding's holistic benefits in early childhood education are explored, and a meta-thematic analysis investigates its influence on cognitive and socio-emotional domains in preschoolers, emphasizing the need for rigorous evidence-based research.

Keywords Coding education · Early childhood development · Cognitive growth · Socio-emotional development · Preschool curriculum integration

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1 Introduction

Technological developments require new generations to acquire specific skills (P21). As technology has become an integral part of our lives, understanding basic computing structures and applications has become essential knowledge required in the 21st century (Czerkawski, 2015, October). Therefore, it is widely recognized that digital literacy is essential in today's information society (Barendsen & Stoker, 2013). Beyond digital literacy, coding, which refers to using languages that enable computing, is increasingly recognized as a new literacy (Bers, 2020; Burke et al., 2016; Vee, 2013).

When Papert (1980) developed LOGO, the first programming language to support children's mathematical skills, he firmly believed that it influenced children's thinking and led them to think, build, and design in new ways (Papert, 1980, 2000, 2005). Interest in Papert's views, which draw attention to the basic concepts of computer science, has increased. This interest has led to the need to enable individuals to take an active and creative role in the use of new cognitive skills and technologies, such as code literacy, and the promotion of programming skills in the early years as essential educational support (Muñoz-Repiso & González, 2019). Lin and Weintrop (2021) stated that computing and the technologies it enables are reshaping the world, and they emphasized that every aspect of our lives is influenced by technology, from how we work and learn to how we play and socialize. Given this increasing presence in our lives, providing opportunities and tools to help people understand how technologies work and train them to control them is becoming an increasing focus of computer education efforts.

Coding is being promoted as a new literacy for all students at all levels of education, including very young children, and is seen as a necessity of the 21st century (Bers, 2019; Lye & Koh, 2014). For this reason, in recent years, efforts to teach coding and computational thinking, the basic concepts of computer science, in early years and to integrate them into educational processes have increased. These efforts have also accelerated classroom practices and research in this field. However, the studies focus on children's coding and computational thinking skills (Macrides et al., 2022; Papadakis et al., 2016; Popat & Starkey, 2019). However, Papert (1980) stated that children's building using technology and writing code is a new way of thinking for children and that children develop many skills while writing code. For this reason, it is necessary to examine and support the effects of coding on children's developmental areas in preschool.

2 Overview

Coding is defined as an essential 21st-century skill and literacy that affects all areas of life (Bers et al., 2019; McLennan, 2018; Monteiro et al., 2021; Vee, 2013), which is defined as the process of writing the correct syntaxes in a ruleful and sequential manner using command sets and developing applications in order to solve problems, provide human-computer interaction, and enable computers to perform a specific task (Bers et al., 2019; Demirer & Sak, 2016; Fesakis & Serafeim, 2009; Kalelioğlu et al.,

2016; Li et al., 2020; McLennan, 2018; Vorderman, 2019; Wing, 2006). Coding is the process of developing systematic ways to solve problems by creating algorithms, which are a set of instructions used to describe each step to perform a specific task or solve a problem (Campell & Walsh, 2017; Ching et al., 2018; Lee & Junoh, 2019; Lee & Björklund Larsen, 2019; McLennan, 2017; Vorderman, 2017). The thinking style in coding is seen as the process of numerical thinking, solving problems using algorithms and developing a logical approach, analyzing and organizing data, dividing problems into small and manageable parts, transforming them into specific algorithms, and transforming and organizing them into programming languages (Arabacıoğlu et al., 2007; Bers et al., 2019; Futschek, 2006; Futschek & Moschitz, 2011; Gibson, 2012; Li et al., 2020; Sullivan et al., 2017; Van-Roy & Haridi (2004).

2.1 Coding in preschool

Coding, a new form of literacy, has become a fundamental tool for reading and interpreting data and communicating with others in a digital society, providing an opportunity to connect children with technology. Thus, coding goes beyond algorithmic thinking and offers children a symbolic language to read and write (Bers, 2018a, 2018b; McLennan, 2017). Despite different conceptual approaches, coding, which is seen not only as a set of technical skills but also as a social and cultural issue involving different fields of knowledge, basically involves thinking like a computer scientist (Grover & Pea, 2018), creating and collaborating (Kafai & Burke, 2014), and using computing languages, which are especially important for future generations (Monteiro et al., 2021). Bers (2019) argues that, similar to natural languages, children should be introduced to and familiarized with these new artificial languages from an early age. Monteiro et al. (2021) emphasize that this artificial language should develop children's perceptual, expressive, and creative skills and lay a strong foundation for developing critical and functional competencies. They also cite understanding "artificial languages" used to create digital structures and transformations as a fundamental skill. In this context, Rushkoff (2010) states that being able to use the language of computers is emerging as an inevitable skill that allows us to participate fully and effectively in the digital reality that surrounds us. González (2015) and Bers (2019) state that individuals will join the new world as code literate when they can read and write in the language of computers and other machines and think numerically.

The literature emphasizes that coding as literacy in preschool education enables the development of personal and social skills that enable children to express, share, and create using computer science languages, ways of thinking, and creativity (Bers, 2020; Grover & Pea, 2018; Kafai & Burke, 2014; Monteiro et al., 2021; Resnick & Rusk, 2020; Vee, 2013). Coding is increasingly recognized as a new literacy that should be encouraged at the right age (Monteiro et al., 2021). In recent years, countries and scholars have emphasized the importance and necessity for children to develop the fundamental understandings, skills, and thinking approaches emerging in computer science, such as coding, programming, and computational thinking (García-Valcárcel et al., 2017; Liu et al., 2017; Webb et al., 2017; Wilson et al., 2010). Education stakeholders have begun to emphasize that coding, like mathematics and

literacy, is essential for everyone. On January 17, 2018, the European Commission presented a new “Digital Education Action Plan” for Europe to help educational institutions and education systems better adapt individuals to live and work in an era of rapid digital change (Bocconi et al., 2018; Webb et al., 2017; Wilson et al., 2010). The European Commission has also taken an active role in this regard and started to promote coding as today’s literacy (Moreno-León et al., 2015).

When the studies on coding skills are examined, it is emphasized that coding provides children with an essential skill necessary for participation in the digital society and contributes to developing all children into computational participants (Kafai & Burke (2014). In addition, while coding develops children’s critical and creative thinking skills, it also supports their computational competencies (Grover & Pea, 2013). The coding process develops problem-solving, reasoning, acquisition of mathematical concepts, meta-cognitive skills (Akyol-Altun, 2018; Baytak & Land, 2011; Clements & Nastasi, 1999; Çiftçi & Bildiren, 2019; Fessakis et al., 2013). (Israel et al., 2015; Lai & Yang (2011) Lambert & Guiffre, 2009; Sengupta et al., 2013); creative thinking skills (Kim, Chunk, & Yu (2013). As Papert (1980), one of the pioneers of computer science education, emphasized, coding can be generalized for children’s lifelong learning and development, giving them a valuable intellectual structure. In the last decade, numerous research and policy initiatives have focused on the conceptual and technical aspects of introducing coding to young children and the cognitive and social aspects underlying this trend (Monteiro et al.)

Studies on coding in early childhood show that intensive efforts are being made to teach coding skills to children in their early years. It is seen that there have been significant developments in areas such as how to teach coding, instructional approaches, and the assessment of these skills. However, it is necessary to reveal how children and educators conceptualize coding in early childhood and their views on its contribution to development.

When studies on coding skills are examined, coding provides a fundamental skill necessary for participation in the digital society and significantly contributes to children’s developmental areas. According to Papert (1980), one of the pioneers of computer science education, coding can be generalized for children’s lifelong learning and development. It can equip them with a valuable intellectual structure. In the last decade, numerous research and policy initiatives have focused on the conceptual and technical aspects of introducing coding to young children and the cognitive and social aspects underlying this trend (Monteiro et al.).

2.2 The effect of coding on development

Many countries have incorporated coding education into school curricula (Heintz et al., 2016; Hsu, 2019). The United States, 16 European countries (Austria, Bulgaria, Czech Republic, Denmark, Estonia, France, Hungary, Ireland, Israel, Lithuania, Malta, Malta, Spain, Poland, Portugal, Slovakia, and the United Kingdom), as well as New Zealand, Australia, Singapore, and Nordic countries have integrated coding into the curriculum at the national, regional, or local level (Bers 2018b; Bocconi et al., 2018; Digital News Asia, 2015; European Schoolnet, 2015). This effort has made coding a new focus of instructional processes starting from early childhood (Bers,

2018a, 2018b; Barron et al., 2011; Bers, 2018; CSTA, 2020; Grover & Pea, 2013; ISTE, 2019; NAEYC, 2012; US Department of Education, 2010; K-12 CSframework, <https://k12cs.org/>).

In recent years, the widespread use of innovative coding platforms, especially screenless programmable robots, has made it possible to integrate coding into early childhood education (Su et al., 2023), but classroom applications have not gained momentum. However, Macrides et al. (2022) and Papadakis et al. (2016) revealed that these studies were primarily aimed at supporting coding and IS skills. Popat and Starkey (2019) stated that the revival of coding in the school curriculum promises to prepare students for the future beyond just learning to code. In their review, Popat and Starkey (2019) found that various other educational outcomes, such as problem-solving, critical thinking, social skills, self-management, and academic skills, can also be learned through teaching coding.

2.3 Effects on cognitive development

There is still a limited understanding of the effects of learning to code on the cognitive development of young children. Although more studies are needed in this area (Relkin et al., 2021), studies prove the positive effects of coding on children's cognitive attitudes, knowledge, and skills (Bers et al., 2014; Çiftci & Bildiren, 2020; Sullivan & Bers, 2016). Coding contributes to developing these skills involving analysis, problem-solving, concept development, transforming problems into specific algorithms and programming languages (García- Peñalvo et al., 2016), and spatial reasoning and logic (NAEYC, 2012). García- Peñalvo et al. (2016) argued that since children develop their thinking skills through language, learning to use a programming language involving logical sequencing, abstraction, and problem-solving also supports their analytical thinking skills. In a rapidly changing digital society, coding is thought to be useful for children to develop computational thinking skills (Bers et al., 2014; Chou, 2020), mathematical thinking (Goldenberg & Carter, 2021), problem-solving, critical thinking, and higher order thinking (Ackermann, 2001; Bers et al., 2002; Bers, 2010; Bers & Horn, 2010; Clements & Gullo, 1984; Clements & Meredith, 1993; Kazakoff & Bers, 2012; Lee et al., 2013; Popat & Starkey, 2019; Portelance et al., 2016; Strawhacker et al., 2015).

Coding helps develop cognitive abilities such as systematic thinking, problem-solving, relationships between events, and creative thinking (Fesakis & Serafeim, 2009). For this reason, studies are showing that coding practices contribute significantly to children's cognitive development (Grover & Pea, 2013; Kazakoff & Bers, 2012; Kazakoff et al., 2013; Papadakis et al., 2016). Recent studies on this subject have examined cognitive development (Flannery et al., 2013), sequencing skills (Caballero-Gonzalez et al., 2019; Kazakoff et al., 2013; Kazakoff & Bers, 2014), problem-solving skills (Akyol-Altun, 2018; Bers et al., 2014; Fesakis et al., 2013; Koç, 2019; Saxena et al., 2020), executive functions (Di Lieto et al., 2017), creativity (Flannery & Bers, 2013; Resnick, 2006; Siper-Kabadayı, 2019; Sullivan & Bers, 2017, 2019; Wang et al., 2011), and computational thinking (Bati, 2022; Bers et al., 2014; Bers et al., 2019; Caballero-Gonzalez et al., 2019; Kalogiannakis & Papadakis,

2017; Kazakoff et al., 2013; Papadakis et al., 2016), and visuospatial skills (Bers et al., 2014; Flannery et al., 2013).

2.4 Effect on social-emotional development

Bers (2020), who sees coding as another language and a new literacy and presents its general framework, refers to coding as “expressive symbolic systems” and “computational thinking tools.” However, she emphasizes that focusing only on information processing ignores the symbolic language aspect of coding, an expressive tool and that a language can be a language when it has a social and a mental side. Moreover, she emphasizes that coding as literacy should include not only thinking like a natural language but also expression and communication or social interaction, which involves doing, creating, and bringing into being. Bers (2008) states that coding, like writing, is a tool for human expression and emphasizes that in this process, children seek new ways of thinking and expressing new ideas and develop new thinking, feeling, and communication skills through this impressive process.

Coding provides the necessary motivation for children to learn programming in more detail and supports their emotional aspects by enabling them to transform ideas into products (Heikkilä, 2020; Toh et al., 2016). Machines have become a part of our lives, and we communicate with them just as we do with other individuals. For this reason, García- Peñalvo et al. (2016) stated that coding enables children to collaborate better with machines.

Fox and Farmer (2011) state that children not only manipulate objects and learn rules while creating concrete products through coding but also write codes, build artifacts in virtual environments, and review, share, and revise them. For this reason, it is emphasized that coding activities allow students to cooperate with their peers and provide highly sustainable participation in problem-solving and reasoning (Fox & Farmer, 2011). Studies have found that computers can act as a catalyst for social interaction in early childhood education classrooms (Clements, 1999) and that children have twice as much social interaction in front of computers as in other activities (Svensson, 2000) and speak twice as many words as in non-technology-related activities (New & Cochran, 2007). Coding education, whether provided through block-based applications or robotic tools and activities, can improve children’s peer collaboration, communication, and social relations (Bers et al., 2019; Lee et al., 2013, 2017; Sullivan & Bers, 2018; Wartella & Jennings, 2000), social development and socially oriented development (Bers, 2012; Caballero-Gonzalez et al., 2019; Critten et al., 2022; Fessakis et al., 2013; Flannery et al., 2013; Pugnali et al., 2017; Strawhacker & Bers, 2015) and self-regulation skills (Kazakoff, 2014).

The findings of this study provide evidence that coding contributes to some children’s developmental areas. In addition, the opinions and perceptions of the participants regarding coding are also seen as a factor that will contribute to the field. The views of children who receive coding education and teachers who work with children on the effects of coding on development are considered necessary to guide the studies conducted in this field and the practices and curricula to be developed.

2.5 Review studies on coding

Many systematic analysis studies have been conducted on coding at the K-12 level. Lye and Koh (2014), who conducted one of these studies, revealed that empirical studies on early childhood are lacking. However, since Lye and Koh (2014) drew attention to the deficiency in the field of early childhood, it is seen that studies in this field have increased rapidly. With this increase, the studies conducted in this field have started to be analyzed. There are a limited number of review studies conducted for preschool children. Papadakis et al. (2016) present a literature review including 18 studies on how the ScratchJr application affects children's CT, coding, and general literacy skills in preschool. The study emphasized that ScratchJr seems to be a helpful application that positively affects children's IT and coding skills. Popat and Starkey (2019) included 11 studies in their review study to analyze the educational outcomes of children learning coding at school. Of these studies, only one was on the problem-solving skills of 5-6-year-old children. Other studies are primarily studies for primary school children. Popat and Starkey (2019) stated that the studies show that students can learn coding and that they can learn several other educational outcomes (such as mathematical problem-solving, critical thinking, social skills, self-management, and academic skills) through coding instruction.

Sulistyaningtyas et al. (2021, September) reviewed 9 studies on coding for early childhood children between 2015 and 2020. This review includes two main objectives: coding practices in early childhood and the impact of coding on early childhood development. In the study, unplugged and plugged activities were used in early childhood, and Children's planning and inhibition skills in communication, collaboration, and creativity were stated as learning outcomes. Macrides et al. (2022) analyzed the studies on programming in early childhood education. This review study analyzed 34 studies for children aged 3–8 years. Of these studies, 5 were conducted with children over 6. These findings show that there has been a significant increase in studies on preschool children in recent years. The intervention programs examined in these studies primarily focus on teaching coding (11 studies) and IT skills (11 studies), with limited attention given to supporting children's overall development. Among the studies targeting developmental areas, the emphasis is mainly on cognitive aspects, particularly problem-solving and creativity. Zurnacı and Turan (2022) reported that, in Turkey, there were 30 studies on preschool coding, consisting of 11 qualitative, 11 quantitative, and 4 mixed-methods studies. These studies predominantly address coding and IT skills but also address academic, cognitive, language, and social skills.

Su et al. (2023) reviewed 20 studies on early childhood coding curricula published in 2012–2021. In this study, educational practices for children were examined in depth. In this review, how the curricula in educational practices for children are designed, which coding platforms or applications are used, what pedagogical approaches are used, research methods, and findings obtained from these studies were examined in depth. In recent years, educational approaches to support preschool children's coding skills have increased, and robotics, Web 2.0 tools, and web-based applications have been developed to support children's coding skills. These studies have revealed that children can acquire coding skills early on. However, it is essential to examine how coding skills contribute to children's other developmental areas and

to develop research and applications in this field. This review of coding has contributed significantly to the current state of the art in this field, as well as the needs and future research. Resnick and Rusk (2020) note that over the past decade, they have seen that it is possible to extend coding experiences to millions of children worldwide. At the same time, they emphasize that there are extraordinary challenges, that coding has been introduced in ways that undermine its potential and promise in many places, and that educational strategies and pedagogies to introduce coding must be carefully discussed. For this reason, in addition to the quantitative data on coding, it is thought that knowing how teachers and children interpret coding can shed light on similar future studies. For this reason, this study aims to shed light on future studies by comprehensively examining qualitative studies on preschool children and the effects of coding on children's developmental areas in these studies.

3 Methodology

3.1 Research model

This research endeavors to ascertain the impact of coding instruction on preschool-aged children's cognitive and socio-emotional development. The primary objective of this investigation is to undertake a systematic analysis of qualitative primary data, discerning recurring themes and topics elucidating the effects of coding education on children's development. This analytical process culminates in synthesizing these identified themes and topics, ultimately facilitating the derivation of comprehensive conclusions. In the context of this research, the meta-thematic analysis approach is recurrently utilized to meticulously dissect the primary qualitative data (Thomas & Harden, 2008). Specifically, this study adopts a meta-thematic framework to synthesize qualitative studies concerning preschool children and their engagement with coding education. Within the purview of the meta-thematic analysis, three overarching themes are meticulously examined:

Theme 1: "What are the cognitive ramifications of incorporating coding education in preschool settings?"

Theme 2: "What are the socio-emotional implications stemming from integrating coding education in preschool contexts?"

Theme 3: "What are the comparisons of theses data and research articles data?"

These themes provide the structural foundation for the comprehensive investigation into the multifaceted impacts of coding education on preschool-aged children's cognitive and socio-emotional development.

3.2 Studies included in the study

In this study, studies on coding education at the preschool education level were investigated within the scope of meta-thematic analysis. The criteria for the inclusion of the study in the meta-thematic analysis were determined as follows:

- Being at the level of preschool education (0–6 years),

- Aiming to measure the effects and limitations of coding education on students' cognitive, emotional, and social context,
- Scientifically qualified and sufficient,
- Including direct participant views,
- Being an experimental study,
- Being a thesis or article,

The studies were selected according to these criteria.

In the study, seven databases, including "Science Direct-SD," "Taylor and Francis-TF," "Higher Education Council Thesis Center (YokTez-YT)," "Dergipark," "ProQuest-PQ," ERIC-E," and "Web of Science-WOS," were utilized. The databases were searched with the keywords "preschool coding," "early childhood coding," "computer-free coding," "preschool programming," and "early childhood programming."

The articles and theses searched in the database were selected based on the above criteria. At the end of this study, 942 studies had been reached. Based on the criteria at the end of the evaluation, 13 articles were included in the meta-thematic analysis. The number of included and excluded studies in the meta-thematic analysis is presented in Fig. 1 using the PRISMA flow diagram (Moher et al., 2009).

According to the criteria presented in the PRISMA flow diagram in Fig. 1 and 942 studies examining the research topic were reached. Based on the evaluation according to the research criteria, some studies were eliminated by not being included in the meta-thematic analysis. Two of the studies scanned in the databases were eliminated due to duplication. Another 653 studies were eliminated from the remaining studies due to irrelevant topics. Of the remaining 287 studies, 182 studies were eliminated because they were not suitable for the primary purpose as a result of abstract screening. Of the remaining 105 studies, 88 were eliminated due to qualitative evaluation. Of these studies, 62 were eliminated because there was no qualitative interview data, and 26 were eliminated because there was no experimental study. Among the remaining 17 studies, as a result of the research conducted at the level of the findings, it was determined that the data of four studies needed to be sufficient and appropriate in terms of content and were eliminated. Thus, 13 studies were reached as a result of the screening. This study is limited to 13 studies accessed during the meta-thematic analysis process and included in the analysis. Although this situation is considered a limitation of the study, it follows the nature of meta-thematic studies (Batdı, 2017, 2019).

The reasons for not including the studies that were not included in the meta-thematic analysis are shown in Table 1. Accordingly, 942 studies were collected from 7 databases, and 929 were eliminated for the reasons shown in Table 1. 13 studies were included in the meta-thematic analysis.

General information on the articles and the theses used in this study is given in Table 2 below.

The provided sources offer a diverse range of perspectives and insights on the integration of coding into education. Despite this diversity, the common thread across all sources is their emphasis on the importance and benefits of integrating coding into educational settings. They highlight how this integration can address various

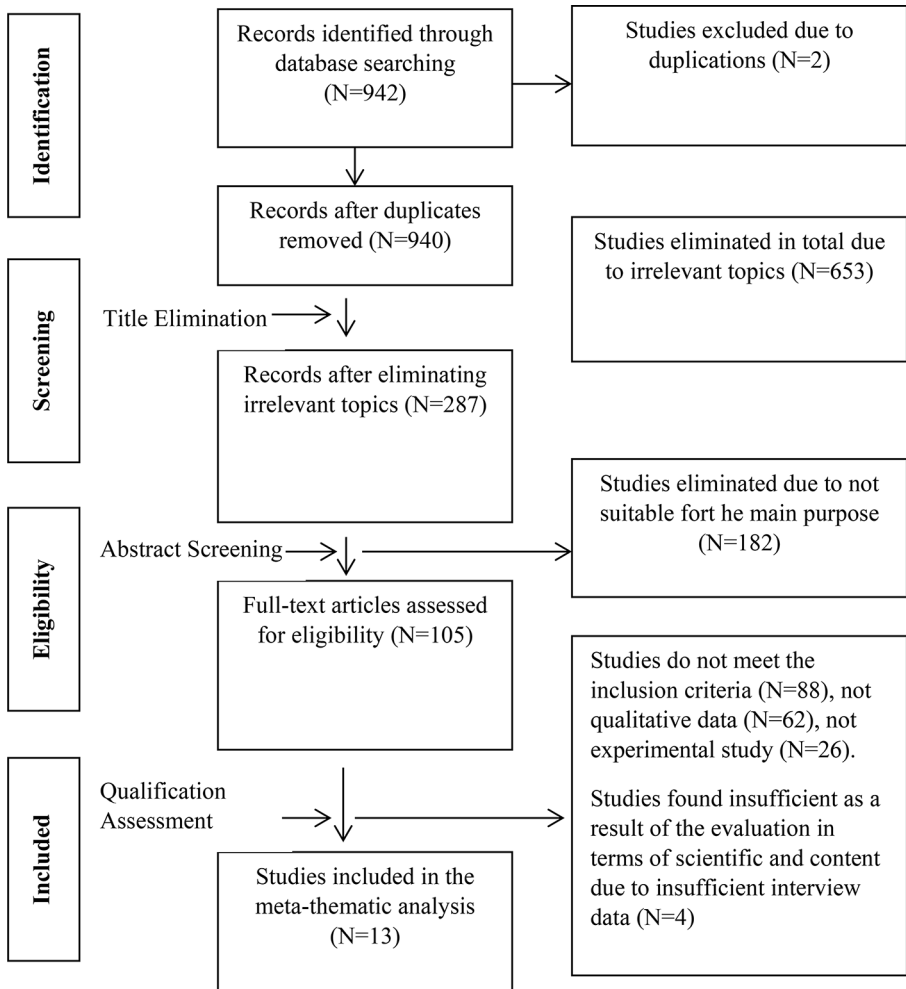


Fig. 1 Flow diagram of the studies included in the meta-thematic analysis

challenges educators face, such as teaching abstract concepts, fostering creativity, and enhancing problem-solving skills among students. Moreover, the sources underscore the significance of providing resources and support for educators to incorporate coding into their teaching practices effectively. However, differences emerge in the themes explored and the depth of analysis offered. For instance, some sources delve into the practical challenges educators face in implementing coding activities (E1, SD), while others focus on the pedagogical benefits and implications of such integration (WOS, PQ). Overall, while the sources vary in their approach and emphasis, they collectively advocate for integrating coding as a valuable tool for enhancing education and preparing students for the demands of the digital age.

Table 1 Number of studies included and excluded in the analysis

	Science Direct	Taylor and Francis	Yök Tez	Dergipark	ProQuest	ERIC	Web of Science	Total
Total number of articles scanned and accessed	248	136	106	21	94	214	123	942
Eliminated due to irrelevant topics	233	95	80	3	51	110	82	654
Remaining after title and abstract screening	15	41	26	18	43	104	41	288
Summaries unsuitable for the primary purpose	9	23	9	14	23	88	17	183
Number of full texts evaluated	6	18	17	4	21	17	24	105
Eliminated for not meeting the criteria	5	18	11	4	17	10	23	88
Insufficient in terms of scientific content	0	0	0	0	3	1	0	4
Included in the meta-thematic analysis	1	0	6	0	1	4	1	13

4 Findings

The codes obtained in the meta-thematic analysis related to coding education in preschool were grouped under three themes. In this context, the titles “Contributions of coding education in preschool to the cognitive domain,” “Contributions of coding education in preschool to a social-emotional domain,” and “Comparison of these data and research articles data” were accepted as themes.

In the current study, the theme created by the researcher related to the research topic and the codes that make up the theme were discussed separately and presented with the findings. At the same time, in interpreting the findings, the sources from which the codes were referenced were directly quoted and supported by the presentation of the themes and codes.

4.1 Contributions of coding education in preschool to the cognitive domain

In the meta-thematic analysis, the sub-problem of the research, “Contributions of coding education in preschool to the cognitive domain,” was taken as a theme. Participant opinions were analyzed in the studies, and codes were created regarding their statements. Codes were created for features such as coding education in preschool, developing students’ intelligence, developing cognitive skills, and reinforcing what is learned.

As a result of the meta-thematic analysis, three sub-categories and ten codes were reached under the theme “Contributions of Coding Education in Preschool to Cognitive Domain.” These codes are shown in Fig. 2; Table 3 with the frequency and

Table 2 General information on the studies used in the meta-thematic analysis

Study code	Database	Study name	Author	Date	Type	Instrument used	Sample
WOS	Web of Science	Dancing Robots: Integrating Art, Music, and Robotics in Singapore's Early Childhood Centers	Amanda Sullivan-Marina Umaschi Bers	2017	Article	KIBO	98 young children, 3–6 years old
YT1	YokTez	Algorithm and Coding Education in Preschool Teaching Program Integration the Effectiveness of Problem-Solving Skills in Students	Canan Akyol Altun	2018	Master Thesis	OSMO coding	5 years old; 30 young children
YT2	YokTez	Investigation of Programming Education Applications in Preschool Education Institutions	Fatma Parmaksız	2019	Master Thesis	Computer-free coding/ Lego, Bbot/ cubetto	104 young children, 5–6 years old
E1	ERIC	Designing Unplugged and Plugged Activities to Cultivate Computational Thinking: An Exploratory Study in Early Childhood Education	Anika Saxena, Chung Kwan Lo, Khe Foon Hew, Gary Ka Wai Wong	2019	Article	Computer-free coding/ Scratch jr	11 young children; 3–6 years old
SD	Science Direct	Coding As a Playground: Promoting Positive Learning Experiences in Childhood Classrooms	Marina U. Bers, Carina González-González, M Belén Armas Torres	2019	Article	KIBO	172 young children; 3–5 years old
YT3	YokTez	The Effects of Robotic Activities on Preschool Children's Creative Thinking Skills	Gamze Siper Kabadayı	2019	Master Thesis	Robotic coding	12 young children, 5–6 years old
YT4	YokTez	Exploring the Effects of Productive Children: Coding and Robotic Education Program in Early Childhood Education	Merve Canbeldek	2020	Doctoral Thesis	Computer-free C./ Block Based C./ Robotic C.	80 young children, 5–6 years old
PQ	ProQuest	Pre-Service Preschool Teachers' Opinions About Using Block-Based Coding/Scratch	Serkan Timur, Betül Timur, Elif Güvenç, İlknur Us, Eylem Yalçınkaya-Önder	2021	Article	Scratch	28 pre-service teachers

Table 2 (continued)

Study code	Database	Study name	Author	Date	Type	Instrument used	Sample used
E2	ERIC	The Effect of Structured Material-Supported Collaborative Coding Workshops in Preschool Education on Students' Basic Skills	Aysel Arslan & Sebahattin Kartal	2022	Article	Computer-free coding	35 young children, 5–6 years old
YT5	YokTez	Analysis of Augmented Reality-Supported Programming Training Created with Participatory Design	İpek Işık Arslanoğlu	2022	Master Thesis	Code-Lim-bel-coding cubes	61 young children, 5–6 years old
E3	ERIC	Understanding Problem-Solving Processes of Preschool Children in CS- Unplugged Activities	Ünal Çakıroğlu, Şüheda Mumcu, Melek Atabay, Merve Aydın	2022	Article	code.org/ computer-free coding	11 young children, 4–5 years old
YT6	YokTez	Investigation of the Effects of the Coding Education Program on Cognitive Flexibility and Computational Thinking Skills of Children Aged 5	Şeyma Değirmenci	2022	Doctoral Thesis	OSMO coding	58 young children, 5 years old
E4	ERIC	"My Cars Do not Drive Themselves": Preschoolers' Guided Play Experiences with Button-Operated Robots	Jacob A. Hall & Kate I. McCormick	2022	Article	Bee-bot	29 young children, 5 years old

percentage values. Two experts (academicians) from the field of educational sciences worked on the codes and grouped them into three sub-themes.

The skills development sub-category covers the skills that students are expected to develop, especially those widely referred to as 21st-century skills. During the coding process, it was observed that students especially developed these skills. The codes in the learning enhancement sub-category cover the skills that need to be acquired in daily life and learning towards the permanent learning process. In this case, it is an essential skill that emerges in the final learning process. Interdisciplinary contribution is an important dimension in education that is becoming increasingly important today. In this study, it emerged as a sub-dimension, albeit a very small one.

Table 3 shows that the codes are grouped around three sub-categories. Among these sub-categories, skills development has the highest rate, with 75.3%. Learning enhancement is the sub-category with the second highest rate of 23.6%. Interdisci-

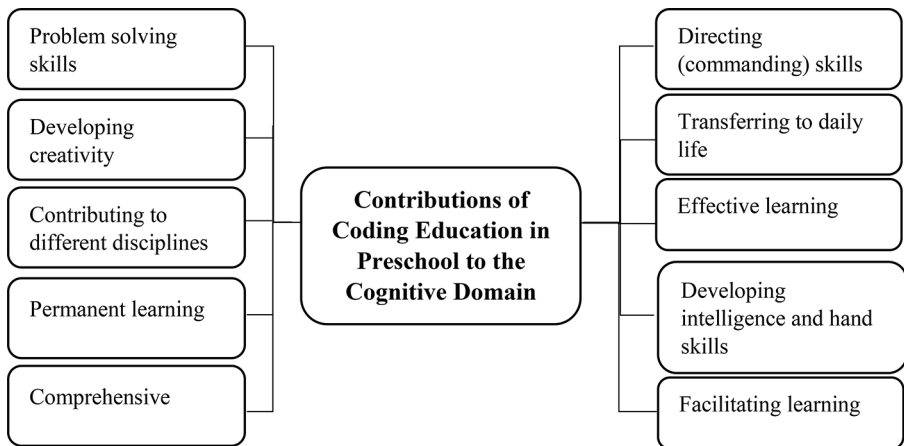


Fig. 2 Contributions of coding education in preschool to the cognitive domain

Table 3 Frequency and percentage values of the codes belonging to Theme 1

Sub-categories	Codes	F	%
Skills development	Problem-solving skills	47	26,4
	Directing (commanding) skills	44	24,7
	Developing creativity	26	14,6
	Developing intelligence	17	9,6
Learning enhancement	Transferring to daily life	14	7,9
	Effective learning	13	7,3
	Permanent learning	6	3,4
	Facilitating learning	7	3,9
	Comprehensive	2	1,1
Interdisciplinary contribution	Contributing to different disciplines	2	1,1

plinary contribution is the sub-category with the lowest rate of 1.1%. In this context, it can be said that coding education develops skills in preschool children in general.

These codes belong to the skills development sub-category. The contribution of coding education in the cognitive dimension was to develop problem-solving skills with 26.4% and directing (commanding) skills with 24.7%. This skill can also be expressed as a computational thinking skill. This code emerged from the statements about students giving commands to the robot or computer and directing it. In the thesis coded YT3-p.73, the statement “*Then it would be like this. First, I program it to turn silently, then play a birthday song, and then turn it off.*” “*It is to teach ways to tell tools such as computers and phones what to do.*” In the article coded E3-p.10, the statement “*I need to stick the arrows in the right direction and take this character to dinner by following the path...*” can be shown as an example.

The code for problem-solving skills was found 47 times in the studies. Some of the statements referenced in this code are “*I believe that it will contribute to the development of children’s abilities in areas such as thinking skills, logic development, problem-solving, etc.*” in the article coded E2- p.753. In the thesis coded YT2-p.55,

the statement *“It is an approach that provides problem-solving, creativity and analytical thinking skills.”* can be given as examples.

For the code related to the development of creativity: in the thesis coded YT6-p.117, the statement *“They did not have difficulty in applying the new rule as before, they created new rules themselves and turned this situation into a new game”* in the thesis coded YT1-p.68, the statement *“We adjust those things when we press it, it does the coding we want, it does the coding according to our imagination.”* and in the article coded PQ-p.304, the statement *“It develops creative thinking and improves cooperative learning. It was collaborative training because we carried out the activities in two groups.”*

These codes serve as crucial indicators of the impact of coding education on cognitive dimensions, showcasing its role in enhancing problem-solving skills, directing abilities (such as computational thinking), and fostering creativity among students. They are supported by specific statements and instances extracted from the qualitative research studies, demonstrating real-world applications and observations.

These codes belong to the learning enhancement sub-category. The references related to the code of transferring to daily life: in the thesis coded YT4-s.119, the statement *“There were touches about life-related to the general program. In other words, you always tried to associate it with life rather than sitting down and doing fashion mode robotics training...”* and in the thesis coded YT3-p.76, the statement *“They reach places that we cannot reach... For example, lifting large items...”* can be given as examples.

Regarding the effective learning code: In the article coded E1-p.63, the statement *“Taking some concepts through disconnected activities that they already had some experience with and using them to apply them with technology helped them respond quickly and understand better.”* can be given as an example.

Codes related to permanent learning: In the thesis coded YT6-p.115, statements *“They did not forget the order of events in the story. Each child made small changes in the story for his/her next friend, and the other child had no difficulty remembering or practicing.”* Regarding the code of facilitating learning: In the thesis coded YT4- p.120, the statement *“...They had much difficulty in the activities we did about graphics. At the end of the training process, they were able to do such activities much more easily.”* can be given as an example. Regarding the statement in which the code for being comprehensive was revealed: In the article PT4- p.119, the statement *“The activities in the implemented education program were very comprehensive and numerous. Turkish language, art, science, mathematics, drama, play, etc. activities in the preschool program were all included, ..”* can be given as an example.

These codes collectively illustrate how coding education transcends theoretical learning, promoting practical application in daily life, improving learning efficacy, supporting long-term knowledge retention, enhancing skill mastery, and contributing to a comprehensive educational experience across different subject areas.

These codes belong to the interdisciplinary contribution sub-category. For the code of contributing to different disciplines: in the article coded PQ-p.311, the statement *“For example, I can use it in animals, colors, shapes, internal organs, and mathematics activities.”* can be given as an example. Regarding the code for the development of intelligence and manual skills: in the article coded E2-p.755, the statement *“I think*

it was beneficial for the development of intelligence. Being careful helped a lot in the development of manual skills. I also believe using the materials will improve the sensory organs.” can be shown as an example.

These codes emphasize the broad spectrum of benefits associated with coding education. They show how coding contributes to diverse subject areas and is pivotal in enhancing cognitive abilities, fostering manual dexterity, and potentially improving sensory perception through materials and hands-on experiences.

4.2 Contributions of coding education in preschool to the social-emotional domain

In the meta-thematic analysis, the sub-problem of the study, “*Contributions of coding education in preschool to the social-emotional domain,*” was taken as a theme. The participants’ opinions in the articles and theses obtained from the research were examined, and codes were created regarding their statements. Codes such as motivating, fun, and cooperative learning were created for coding education in preschool. As a result of the meta-thematic analysis, eight codes were found under the theme “Contributions of coding education in preschool to a social-emotional domain.” These codes are given in Fig. 3. In addition, Table 4 below shows the frequency and percentage values of the codes.

As a result of the meta-thematic analysis, two sub-categories and eight codes were reached under the theme “Contributions of Coding Education in Preschool to Social-Emotional Domain.” These codes are shown in Fig. 3; Table 4 with the frequency and percentage values. Two experts (academicians) from the field of educational sciences worked on the codes and grouped them into two sub-themes.

These sub-categories encompass crucial facets of comprehensive growth. Social and behavioral development entails the acquisition of proficiencies indispensable for efficacious engagement, collaboration, and adjustment in diverse social contexts. Personal development and empowerment concentrate on individual advancement, nurturing resilience, self-assurance, and self-governance to empower individuals to navigate life with certitude. In unison, these categories epitomize manifold dimensions of human maturation and skill enhancement.

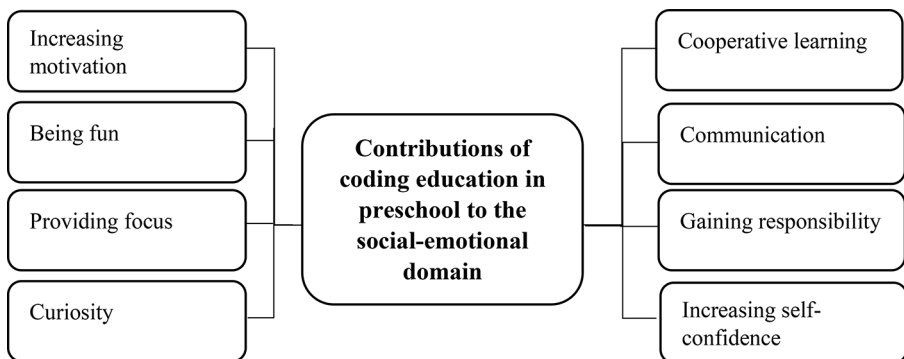


Fig. 3 Contributions of coding education in preschool to the social-emotional domain”

Table 4 Frequency and percentage values of the codes belonging to Theme 2

Sub-categories	Codes	F	%
Social and behavioral development	Being fun	21	25,9
	Cooperative learning	18	22,2
	Communication	13	16,0
	Curiosity	10	12,3
Personal development and empowerment	Increasing motivation	8	9,9
	Gaining responsibility	6	7,4
	Increasing self-confidence	3	3,7
	Providing focus	2	2,5

Table 4 shows that the codes are grouped around two sub-categories. Social and behavioral development has the highest rate among these sub-categories, with 76.5%. Personal development and empowerment is the sub-category with the second highest rate of 23.5%. In this context, it can be said that coding education develops social-emotional aspects in preschool children in general.

These codes belong to the social and behavioral development sub-category. The code with the highest percentage value was the code of being fun, with 25.9%. Codes related to being fun: In the thesis coded YT6-p.118, the statement “*They had much fun in the game of reaching the nest through obstacles. They put the obstacles in different places and continued to play.*” and in the article coded PQ-p.309, the statement “*It should be included in the school curriculum. It provides cognitive thinking as it both entertains and provides problem-solving skills and even cooperation...*” can be given as an example.

The codes related to supporting cooperative learning and communication can be referenced as follows: “*In the field of social-emotional development, the fact that children look for solutions together, communicate and help each other during programming activities supports the development of collaborative attitude in children.*” in the thesis coded YT2- p.64 and “*...The fact that group activities were given much space and the groups were mixed strengthened their communication.*” the thesis coded YT4- p.120 can be given as examples. Regarding the curiosity code: In the thesis coded YT5- p.78, the statement “*I want to place the cubes immediately for my character to move.*” can be exemplified.

These codes underscore how coding endeavors impart technical proficiencies and yield considerable benefits towards cultivating intangible skills, such as collaboration, proficient communication, and inherent drive and intellectual inquisitiveness, among students.

These codes belong to the personal development and empowerment sub-category. In the present study, 9.9% was found for the code of increasing motivation. The statement “*They were also eager to put the blocks together to create different dances.*” In the articles WOS- p.341 and SD- p.142, the statement “*... KIBO was an extraordinary source of motivation for our students*” can be cited as examples. About the code related to gaining responsibility: In the article SD- p.141, the statement “*...Progress was made in supporting values such as respect for a partner and their ideas, the ability to wait, the development of responsibility and autonomy, and the care of materials...*”. Regarding the code for increasing self-confidence: In the article PT2- p.64, the statement “*... Learning new things makes children feel good and increases their*

self-confidence. They express that they are happy after the activity.” can be given as an example. Referring to the codes related to providing focus: In the article coded E2- p.754, the statement *“The application contributed to the development of children in areas such as cooperation, sharing, focusing and attention...”* can be exemplified.

These codes highlight how coding education transcends technical skills, fostering personal growth by enhancing motivation, instilling a sense of responsibility, boosting self-confidence, and refining essential behavioral attributes like focus and attention.

4.3 Comparison of theses data and research articles data

When the studies are classified as theses and articles and analyzed in terms of similarities and differences, similarities and differences in Target Age Group, Learning Focus, Main Tools, Activities, Benefits, Challenges, Educational Impact, and Teacher Involvement are given in the table in detail (Table 5).

The data of research articles delves into the educational application of robotics and coding activities, primarily aimed at young children in preschool and early elementary school. The emphasis is on hands-on learning experiences integrating technology tools such as KIBO and Bee-Bot into the classroom environment. These tools are designed to introduce children to foundational concepts of programming and computational thinking playfully and interactively.

One of the key observations from the research articles’ data is the positive impact of these activities on various aspects of child development. Through engaging with robotics and coding, students demonstrate enhanced teamwork by collaborating with peers to solve problems and complete tasks. The iterative nature of these activities

Table 5 Comparisons of theses data and research articles data

Aspect	Theses’ data	Research articles’ data
Target age group	Elementary and middle school students	Preschool and early elementary school students
Learning focus	Creativity, problem-solving, engineering	Computational thinking, coding, teamwork
Main tools	LEGO bricks, motors, sensors	KIBO, Bee-Bot
Activities	Building structures, mechanisms, and robots	Sequencing, programming, interactive storytelling
Benefits	Develops spatial reasoning engineering skills	Enhances teamwork, perseverance, and fine motor skills
Challenges	Complexity of designs, motor programming	Integrating technology, teacher training, age-appropriateness
Educational Impact	Fosters creativity, logical thinking	Promotes collaboration, critical thinking, and coding skills
Teacher Involvement	Facilitates guides exploration	Designs activities, scaffolds learning experiences

encourages perseverance and determination as students persist in their efforts to achieve success, boosting their confidence along the way.

Teachers and researchers also note the benefits of using structured materials, such as wooden blocks, in conjunction with technology tools. These materials provide tangible, hands-on experiences that help students develop spatial reasoning, problem-solving, and fine motor skills. Moreover, using concrete materials ensures that learning activities are accessible and engaging for all students, regardless of their prior experience or background knowledge.

However, integrating robotics and coding into the curriculum presents its own set of challenges. Educators highlight the importance of starting with unplugged, concrete activities to build foundational understanding before introducing technology-based tools. They also stress the need for adequate teacher training and resources to support effective implementation, particularly in designing developmentally appropriate activities and scaffolding learning experiences to meet the diverse needs of students.

In summary, the data from the research articles underscores the potential of robotics and coding activities to foster critical thinking, collaboration, and creativity among young learners. By providing hands-on experiences with technology tools, educators can help students develop essential skills for success in the digital age while promoting a positive attitude towards learning and exploration. However, achieving these goals requires careful planning, ongoing support, and a commitment to inclusive and equitable education for all students.

These data centers around educational activities promoting active participation, problem-solving skills, and curriculum integration. Teachers engage students in diverse activities that target various learning outcomes, including motor skills and cognitive development. These activities are adaptable for different age groups and subjects, allowing for flexibility in implementation.

Teachers reflect on the effectiveness of these activities, considering factors such as student engagement, comprehension, and skill acquisition. While the specific nature of the activities is not detailed, they likely involve hands-on experiences, group collaboration, and exploration of different concepts.

Overall, these data highlight the importance of engaging students in interactive and multidimensional learning experiences that cater to their developmental needs and enhance their understanding of various subjects.

5 Discussion

The fact that computer science is seen as a skill that all individuals should acquire in the early years has increased interest in coding. In addition, innovative coding platforms such as screenless programmable robotics, which have increased in importance in recent years to support 21st-century skills and STEM skills, have increasingly entered children's early years (Macrides et al., 2022). This growing interest in the necessity of coding has increased the efforts of countries to integrate coding into their educational curricula. This increase has also accelerated research in this field. The view that coding is not only about teaching computer science concepts to

children but also about skills and literacy has started to gain importance. The view that coding is a skill that provides children with a new perspective, way of thinking, and behavior has been emphasized. However, Popat and Starkey (2019) and Su et al. (2023) emphasize that recent studies on coding in early childhood have mainly focused on children's coding or computational thinking. Su et al. (2023) pointed out that there are limited studies on the effects of coding on development and that studies should be conducted in this field. Therefore, in this study, qualitative studies on coding were examined to reveal the effects of coding on development. This study has analyzed qualitative studies, considering that they will contribute significantly to this emerging field by examining the work done in this area, what needs to be done in the future, and what kinds of gaps exist.

The meta-thematic analysis aimed to answer the primary research question: "What are the contributions of coding in early childhood education to the cognitive domain?" The findings indicate opinions that coding contributes to directive (command-giving) skills, problem-solving abilities, and fostering creativity. Cognitive-weighted learning outcomes such as transferring knowledge to daily life, effective and lasting learning, and facilitating learning have been highlighted, emphasizing their contributions to various disciplines. Quantitative studies have demonstrated that coding affects sequencing (Kazakoff & Bers, 2012; Kazakoff et al., 2013; Muñoz-Repiso & Caballero-González, 2019), problem-solving (Akyol-Altun, 2018; Bers et al., 2014; Çiftci & Bildiren, 2020; Fessakis et al., 2013), and executive functions (Di Lieto et al., 2017). Furthermore, coding and robotics education have significantly supported early mathematical reasoning skills in children (Blanchard et al., 2010; Caballero-Gonzalez et al., 2019; Di Lieto et al., 2017; Flannery et al., 2013; Kazakoff et al., 2013). Canbeldek and Işıkoğlu (2023) observed that coding and robotics education programs positively affected preschool children's cognitive development, language skills, and creativity. Mısırlı and Komis (2014) found that their implemented program supported the development of mathematical concepts such as sequencing and repetition, algorithmic thinking, measurement, and spatial orientation in children.

Popat and Starkey (2019) highlighted those researchers mentioned that the inclusion of coding in school curricula provides a range of learning outcomes applicable beyond computer science. Meanwhile, Su et al. (2023) reviewed studies on coding in early childhood and emphasized that it is a new field focusing on imparting coding skills. The authors suggested evaluating the effects of coding curriculum on holistic learning outcomes in early childhood, such as school readiness skills (e.g., literacy, numeracy, spatial, and social skills). They emphasized the need to assess more critical child developmental outcomes like language, self-regulation, and metacognitive skills to understand the impact of coding curriculum. Zurnacı and Turan (2022) reviewed studies on coding in preschool education in Turkey, revealing that the most addressed topic was cognitive skills such as problem-solving abilities (in 7 studies), attention, sequencing, and analysis. The findings of this study also demonstrate an emphasis on the limited skills of cognitive development as a multidimensional process related to coding.

The study sought to address the question of "What are the contributions of using coding in early childhood education to the socio-emotional domain?" as the second sub-problem of the research. The study's findings indicated that coding contributes

to the socio-emotional domain by enhancing enjoyment, increasing motivation, fostering collaborative learning, improving communication skills, promoting personal development, empowering through increased motivation for responsibility, enhancing self-confidence, and facilitating focus. Bers (2008, 2012), who studies coding in early childhood, states that children should be motivated while using technology and that working in a social and collaborative environment should support social and emotional skills along with these skills. Based on the positive youth development approach, he developed the PTG approach in programs and applications to be developed for children and applied this approach to his applications. In unplugged and block-based applications, he has drawn the framework of learning environments where children can be motivated while coding and develop their social skills by working collaboratively. He presented a road map to change the perspectives that technology negatively affects children's social and emotional development and to support these areas of development.

Similar studies, like the results of this study, also indicate that coding supports socio-emotional development. Applications focused on coding demonstrate support for children's peer collaboration, communication, and social relationships (Bers et al., 2019; Caballero-Gonzalez et al., 2019; Critten et al., 2022; Fessakis et al., 2013; Flannery et al., 2013; Lee et al., 2013; Sullivan & Bers, 2016; Pugnali et al., 2017). Studies have shown that coding supports children's self-regulation skills (Canbeldek and Işıkoğlu, 2023; Di Lieto et al., 2017; Kazakoff, 2014). Heikkilä (2020) observed that robotics applications supporting coding generated significant interest in children, increased their patience and enthusiasm, and reduced gender-biased perspectives.

The study sought to address the question of "What are the comparisons of these data and research articles data?" as the third sub-problem of the research. These data, which focus on LEGO-based education, primarily target elementary and middle school students, offering activities that foster creativity, problem-solving, and engineering skills. Students build structures, mechanisms, and robots using LEGO bricks, motors, and sensors. This approach benefits learners by developing their spatial reasoning and engineering abilities, although it can present challenges in the complexity of designs and motor programming. Teachers in this context typically serve as facilitators, guiding students through exploration and experimentation.

In contrast, the data of research articles revolves around robotics and coding education for preschool and early elementary school students. It emphasizes computational thinking, coding skills, and teamwork, often using tools like KIBO and Bee-Bot. Students participate in sequencing, programming, and interactive storytelling, which promote collaboration, critical thinking, and fine motor skills. However, integrating technology and ensuring age-appropriateness can be significant challenges for educators in this domain. Teachers play a more active role in designing activities and scaffolding learning experiences to suit the developmental needs of young learners.

While both topics aim to enhance students' learning experiences and skills development, their target age groups, learning focuses, main tools, and teacher involvement differ. LEGO-based education leans towards older students and emphasizes hands-on building and engineering, while robotics and coding education cater to younger learners and prioritize computational thinking and programming skills. Despite these

variances, both approaches contribute to fostering creativity, problem-solving, and critical thinking skills essential for success in the 21st century.

Due to the nature of meta-thematic research (Batdı, 2019), the data used in this study consisted only of articles and theses that presented experimental studies and direct participant views. Therefore, the comparison of articles and thesis studies was limited to these articles. A more detailed comparison is recommended to contribute to the field.

Reviews conducted on coding in early childhood (Lye & Koh, 2014; Macrides et al., 2022; Papadakis et al., 2016; Su et al., 2023) have revealed significant findings. These studies have indicated that intervention programs primarily focus on children's coding and computational thinking skills, with a limited number examining their impact on developmental domains. The present study, however, has demonstrated an understanding of coding's influence on cognitive and socio-emotional development. Furthermore, a significant finding of this study indicates a focus on a few foundational skills within cognitive and socio-emotional development through coding.

Previous review studies have contributed significantly to coding practices, approaches, methods, techniques, materials, and assessments used in these interventions. They have also outlined a framework for studies centered around coding. Additionally, it is believed that identifying views, thoughts, and trends in the field will provide substantial contributions from practitioners or researchers regarding their perspectives on coding, ultimately strengthening and enhancing studies.

This study suggests a trend indicating that coding contributes to cognitive and socio-emotional domains. However, coding is proposed to support various cognitive and socio-emotional development aspects. It is essential to empirically validate and confirm these views concerning the impacts of coding on development through empirical studies.

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Data availability The data used to support the findings of this study are available from the corresponding author upon request.

Declarations

Conflict of interest All authors declared that there are no conflicts of interest.

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