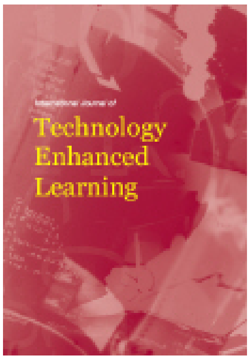

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Coding activities in early childhood: a systematic review

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Abstract: The current study aims to systematically review the literature on teaching basic coding skills in early childhood education, particularly for children aged 3 to 8 years. A systematic literature review was conducted of 45 articles published in Science Direct, Wiley Online Library, SpringerLink, Sage Journals, Taylor & Francis Online, ERIC, JSTOR and Google Scholar on using coding activities in the preschool years from 2014–2023. The review presents empirical research with young learners and reports on relevant frameworks and curricula, the impact of pedagogical approaches and tools on learning, and the learning outcomes and pedagogical benefits of teaching coding. Plugged and unplugged coding activities can be introduced to young learners as a stand-alone subject or integrated into the regular kindergarten curriculum based on the studies reviewed. Additionally, coding can be incorporated into literacy and storytelling activities as a developmentally appropriate approach. The authors conclude that for educators to become competent in introducing coding activities into early childhood education, future research should focus on developing curricula that fully integrate coding and accompanying teacher training programmes.

Keywords: early childhood education; ECE; coding skills; computational thinking; CT; robotics; systematic literature review; PRISMA.

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1 Introduction

The early childhood years are recognised as a time when skills are easily acquired, and the development of the brain is very rapid (Atzil et al., 2018). Children have a natural curiosity and desire to learn (Rivera, 1998). Thus, during this time, children are more flexible in understanding the relationship between events and reason, draw conclusions, are more open to external stimuli and have an increased capacity to change their behaviour (Altıparmak and Öziş, 2005; Atzil et al., 2018). Early reasoning skills development supports later development and learning (Whittaker and McMullen 2014). Early childhood education (ECE) is expected to help children adapt to social life, as well as help them develop some of the basic social and cognitive skills they will need in later years (Demetriou et al., 2017). The ISTE standards of the International Educational Technologies Association (ISTE, 2016) state that due to the rapid advancement of the computer and automation age, students must be knowledge constructors, innovative designers, computational thinkers, creative communicators, global collaborators and empowered learners (Bati 2022). Thus, it is possible to develop computational thinking (CT) among the 21st-century skills that future learners should possess. Due to its integration into educational programmes, CT is one of the most discussed areas. When Wing (2008), first conceptualised CT, it was essential to develop a shared understanding of CT skills and teach them early for everyone to learn. CT is understanding and solving complex problems using computer science concepts and techniques (Chen et al., 2023; Kale and Yuan, 2021). Therefore, teaching coding early will give children a solid foundation for lifelong learning and success.

1.1 Coding education in early childhood

Coding (also called 'computer programming') has been promoted since the 1970s with a constructivist and interdisciplinary vision of learning for children of school age (Feurzeig et al., 2011; Vee – University Of Pittsburgh 2013). Coding follows the trend of computing education, which refers to teaching and learning programming and CT. Put differently, coding is an essential subset of computing. In 2003, Robins and colleagues published a landmark review of research on the teaching and learning of coding, particularly in the adult population (Robins et al., 2003). Coding is being promoted as an emerging literacy for all students, including the very young (Noh and Lee, 2020; Sullivan and Umashi Bers, 2019; Webb et al., 2017), as technology plays an increasingly important role in education. This aligns with the policy agenda to promote STEM (science, technology, engineering and math) education at all levels of education (Callejas et al., 2023; Lye and Koh, 2014; Papadakis et al., 2022).

Recognised as the spoken language of the digital age, coding skills involve developing the instructions for programs to work and writing program commands in a way that computers can understand (D.K, 2013; McLennan, 2017). Children who acquire these skills through playful activities will be able to make the gains that support the cognitive development area they are expected to achieve in ECE programmes (Xezonaki, 2022). The knowledge they learn through quality ECE will positively contribute to their future success as young adults with high school achievement and successful future careers (Bers, 2019; Günes and Kucuk, 2022; Schaefer and Cohen, 2000; Yu and Roque, 2018). Although approximately 500,000 computer science jobs are advertised each month in the USA, there is a need to increase the number of people trained in the field who are eligible to apply for these positions. Given that 1.7 million engineers and experienced people will be needed in coding-related jobs as the need for labour grows, the importance of students developing these skills early is recognised (Code.Org, 2018; Corbett and Hill, 2015).

According to Papert (1980), one of the pioneers of computing education, coding can help provide children with a generalisable and valuable intellectual structure for lifelong learning and development. In a rapidly changing digital society, coding enables children to develop CT (Chou, 2020; Kazakoff and Bers, 2014), mathematical thinking

(Goldenberg and Carter, 2021), literacy (Hassenfeld et al., 2020), and meta – and lower-order thinking skills (Popat and Starkey, 2019). In addition, teaching coding skills at an early age facilitates children's language skills, visual memory, and the teaching of abstract concepts in mathematics and contributes to children's ability to find appropriate solutions to problems, establish cause-and-effect relationships, and sort (Anzoategui et al., 2017; Dağ et al., 2023; Nam et al., 2019; Shumway et al., 2021).

Earlier exposure to coding education is shown to be more sustainable, less costly (Reynolds et al. 2011) and less likely to lead to gender stereotyping in STEM (Burke and Mattis, 2007). Exposing children to programming early makes it easier for them to understand, learn and apply programming in their future lives (Louka, 2022). Research in the field of robotics in the preschool years, the so-called early childhood years, demonstrates the ability of preschool children to learn basic programming concepts such as logical sequences, cause-and-effect relationships and engineering design skills (Fessakis et al., 2013; Kazakoff et al., 2013) Teaching coding skills at a young age also supports the CT of students and the sub-dimensions of CT, such as comprehension, assessment, algorithmic design, abstraction, decomposition and generalisation skills, in a way that is easy to master (Dağ et al., 2023). Moreover, the introduction of coding in the preschool period helps children to develop their ground, direction, movement and mathematical skills, to learn cooperative learning and to take responsibility (Kincal and Yavas, 2021).

Countries worldwide have begun to teach coding in early childhood (Siu and Lam, 2005). In general (Gunes and Kucuk 2022), coding studies have focused on middle school students. For young children (3 to 8 years old), the research on coding education is still in its infancy (Ching et al., 2018; García-Peñalvo, 2017; Mangina et al., 2023). Early coding education introduces young children to basic computer programming concepts and skills such as logic, sequencing, problem-solving and creativity (Goldenberg and Carter, 2021; Hassenfeld et al., 2020; Popat and Starkey, 2019). Coding education can have a positive impact on children's cognitive, social and emotional development (Anzoategui et al., 2017; Dağ et al., 2023; Nam et al. 2019; Shumway et al., 2021) and on their future academic and career prospects (Burke and Mattis, 2007; Reynolds et al., 2011). In order to meet the needs of the present without compromising the ability of future generations to meet their own needs, coding education can also contribute to sustainable

- Promote the digital literacy and innovation needed to handle the complex challenges and opportunities of the 21st century.
- Promote equity and inclusion by ensuring that all children, regardless of gender, background or location, have access to quality coding education and the benefits of digital technologies.
- Promote environmental awareness and responsibility by using coding education to teach children about the natural world and how to protect it from artificial threats.
- Promote global citizenship and cooperation by using coding education to expose children to different cultures and perspectives and foster a shared responsibility for the common good.

Therefore, it is essential to recognise early childhood coding education as a valuable and appropriate way to prepare children for the future and support sustainable development.

Coding can be more seamlessly integrated into ECE with the widespread availability of innovative coding platforms, particularly screen-free programmable robotics (Manches and Plowman, 2017). ECE refers to educating and caring for children from birth to age eight (Yang, 2017). Furthermore, little is known about activities designed to teach coding to young children and their effectiveness, although previous studies have introduced these new technologies into E.C.E. classrooms and demonstrated promising effects (Kazakoff and Bers, 2014; Kazakoff et al., 2013; Nam et al., 2019; Yang, 2021). Therefore, there is an urgent need to identify the characteristics and effects of programmes used in these activities by systematically analysing existing studies focusing on early childhood coding activities. In this article, we use a systematic review approach to rigorously and transparently synthesise the evidence on coding activities in early childhood, identify the types of evidence available in this area, examine the research conducted on this increasingly important topic, and point to gaps in knowledge in this area (Munn et al., 2018). A comprehensive and critical review is the aim of this study. It explores and examines the characteristics of early childhood coding activities and successful pedagogical elements that contribute to early childhood coding. In order to maximise the validity of the findings, collect unbiased information and increase the generation of evidence as much as possible, only empirical studies from peer-reviewed journals were selected for the systematic review (Dieste and Padua, 2007). This systematic review aims to provide researchers with a more accurate perspective on coding activities in early childhood.

1.2 Importance of the study

Although coding studies in education are a popular area of research for schoolchildren, it is known in the literature that more research is needed because of recent experiences with coding practices in early childhood (Akiba, 2022; Su et al., 2023). Teachers need guidance due to the children's young age and need to have the skills to assist them in coding to guide the children properly due to their low literacy skills in the preschool years. Therefore, it is essential to understand the trends in the literature and the findings of existing studies.

As a result, this study examines teaching and learning of coding in early years settings, particularly in 3-8-year-olds. In particular, this review study aims to present systematic information, documented by empirical investigations with young learners, about the relevant frameworks and curricular programmes that have been developed, the impact of coding tools on learning, and the learning outcomes and suggestions for implementation steps of the programmes. In addition, considering other factors and conditions that may influence the learning process, this systematic review aims to report on the knowledge, skills and attitudes that can be effectively taught and mastered at this very young age and the assessment types.

1.3 Aim of research

This study aimed to systematically review the articles published in Science Direct, Wiley Online Library, SpringerLink, Sage Journals, Taylor and Francis Online, JSTOR and Google Scholar on coding activities usage in early childhood between 2014 and 2022. For this purpose, answers to the following questions were sought:

1 What is the distribution of articles published in databases on coding in ECE 2020–2022 according to year, country, journal name, research method, sample size and variables?

2 Which skills of children are affected by coding in ECE?

3 Which pedagogical tools have been practical with coding skills in ECE?

4 In studies on coding skills in ECE

   a What recommendations are made for future work?

   b What recommendations were made to teachers?

   c What recommendations have been made to practitioners?

2 Materials and methods

The materials and methods should be described with sufficient details to allow others to replicate and build on the published results. Please note that the publication of your manuscript implies that you must make all materials, data, computer code, and protocols associated with the publication available to readers. Please disclose any restrictions on the availability of materials or information at the submission stage. New methods and protocols should be described in detail, while well-established methods can be briefly described and appropriately cited.

Research manuscripts reporting large datasets deposited in a publicly available database should specify where the data have been deposited and provide the relevant accession numbers. If the accession numbers still need to be obtained at submission, please state that they will be provided during the review. They must be provided prior to publication.

Interventional studies involving animals or humans and other studies that require ethical approval must list the authority that provided approval and the corresponding ethical approval code.

3 Results

This systematic review facilitated a general search of some specific electronic databases and the web search engine for scholarly literature and academic resources. Only peer-reviewed articles or conference papers were included to increase the study's credibility and integrity. The databases searched were Science Direct, Wiley Online Library, SpringerLink, Sage Journals, Taylor & Francis Online, and JSTOR. Google Scholar was also selected due to currently being the most comprehensive academic search engine and to include articles published outside educational journals that provide relevant information. Coding skills have often been associated and referred to with different terms. For example, programming, robotics, educational robotics, gamified applications, gamified environments, gamification, and game-based applications refer to gamification content. According to Cronin et al. (2008), considering alternative terms with equivalent meanings is vital to maximising the amount of information accumulated in an S.L.R. Thus, alternative keywords from the database thesaurus were identified and used in different combinations by utilising ‘Boolean’ operators (AND, OR) (Şahin and Namli, 2016). The terms used in the search string included core concepts that align with our research topic and research questions, such as ‘coding’, ‘teaching of programming’, robotic toys’, and ‘ECE’, as well as synonyms, as shown in Table 1.

Table 1 Core concepts and synonyms

Coding	‘coding’, ‘robotics’, ‘computer science’, ‘technology’, ‘programming’, ‘STEM education’, ‘robotics toys’, ‘teaching of programming’, ‘early coding’, ‘programmable toy’
Educational level	‘early childhood’, ‘preschool’, ‘kindergarten(s)’, ‘elementary education’, or ‘primary education’

After testing and reviewing the specific syntax that each database required, a search string was created by compiling Boolean and simple operators with parentheses. The search string that was used was (‘coding’ OR ‘robotics’, OR ‘computer science’, OR ‘technology’, OR ‘programming’, OR ‘STEM education’, ‘robotics toys’, OR ‘teaching of programming’ OR ‘early coding’ OR ‘programmable toy’) AND (‘early childhood’ OR ‘preschool’ OR ‘kindergarten’ OR ‘elementary education’ OR ‘primary education’). Usually, a search string containing all fundamental concepts and their synonyms was used. However, two databases, Science Direct and JSTOR, had some restrictions on Boolean operators (maximum eight characters) and characters used in the search string (maximum 200 characters). In addition, the database search was adjusted for inclusion or exclusion criteria if options such as publication date, language, etc., were available in the database.

3.1 Inclusion/exclusion criteria

In the interest of conducting our research, we set specific criteria that would help us sift through the variant studies, select and include those relevant to our research topic, and exclude the studies that failed to meet some necessary conditions. The inclusion and exclusion criteria were as follows:

3.2 Inclusion

1 The study must be empirical (quantitative, qualitative, or mixed methods) in a learning environment.

2 An unplugged or plugged coding activity practice was used in the study. The coding activity practice must have been used on learners, and empirical data must be included.

3 The study was conducted in an educational environment (kindergarten, preschool or primary school [Grade 1–Grade 3]).

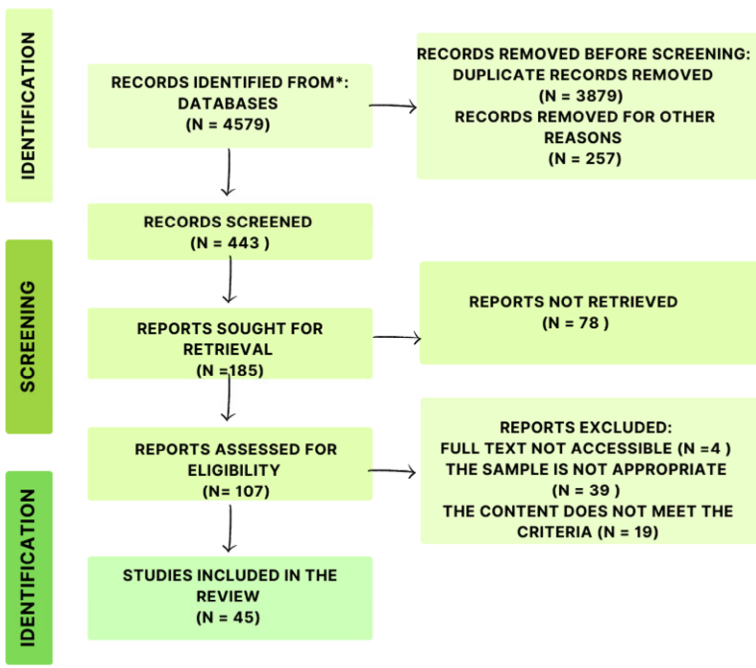
4 The article is a peer-reviewed paper.

5 The article is published from 2014 to 2023. We investigated studies from the past four years to solely include coding practices with new interactive technologies.

3.3 Exclusion

1 The study needs to be written in English.
2 The study does not mention the plugged or unplugged robotic activity used.
3 The study sample level is not ECE.
4 The study is listed in another database.
5 The study is only published as an abstract.

Figure 1 PRISMA review process (see online version for colours)



3.4 Review process

The literature was screened by three independent authors (MU, HG and HU) according to the guidelines provided by PRISMA (Spiteri, 2020). Initial search results across all databases produced 4,579 articles, as shown in Table 2. First, we excluded 4,136 articles based on duplication, publication date, title review and relevance, and abstract review. Then, the titles and abstracts of the documents were analysed, excluding those articles that did not comply with the previously established inclusion criteria. The remaining 107 articles were carefully reviewed concerning our criteria and research questions. A thematic analysis procedure was followed (Braun and Clarke, 2014). The remaining 107 articles were screened for further information. Each author individually kept notes and read each article more than once to properly understand its content, procedures, methods used and findings displayed. All information was then compared and discussed. 45 articles that made up the final dataset were included in the systematic review (Table 2).

Among the studies excluded from the scope of the research, the study by Akiba (2022) was excluded because it was a review study. In another study, a curriculum was introduced in the study conducted by Bers (2019), Kazakoff et al. (2013), and it was not included in the systematic review study because there was no application. The PRISMA process we followed is shown in Figure 1.

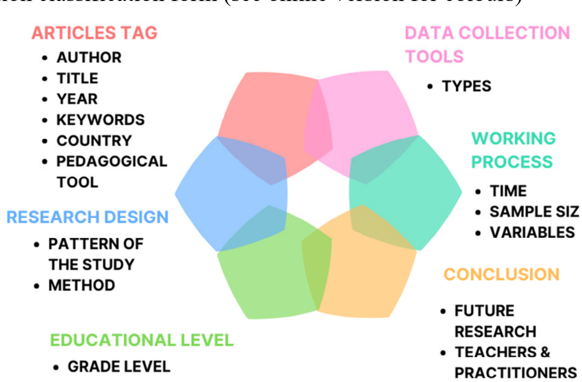
Table 2 Data source and systematic review stages

Data source	*1st stage (Identification)*	*2nd stage (Screening)*	*3rd stage (Included)*
Wiley Online Library	559	15	1
SpringerLink	589	32	14
Sage Journals	319	12	4
Taylor & Francis Online	1,049	25	8
Google Scholar	1,000	8	8
Science Direct	913	15	10
JSTOR	150	-	-

3.5 Data collection tool

The Publication Classification Form was used to analyse the articles in this study. Researchers obtained This form by customising the education technologies publication classification form (ETPCF) (Göktaş and Tellİ, 2012; Sozbilir and Kutu, 2008). Researchers first created a draft form, edited with expert opinions. The form contains the features of the articles, such as author, year, country, journal name and title information. In addition, there are sections detailing which coding activity is used in which variable/s, research method, sample size and the implementation period of the studies. The final form, which includes data collection tools used, variables, conclusions and recommendations, consists of six main headings and 15 sub-headings (Figure 2). Thematic content analysis of the data was carried out, and sub-classification and coding were performed. If more than one outcome was examined in the study, each outcome was coded separately. In this type of coding, the total data comprised the outcomes of the articles examined and analysis rather than the number of studies examined.

Figure 2 Publication classification form (see online version for colours)



A systematic keyword search collected data across all studies while preserving their credibility. To ensure the convergence and verification of our findings, we lastly conducted a document analysis, completing our triangulation procedure. The following essential information was extracted from each article:

1 articles tag (year, country, coding tool)

2 research design (method)

3 educational level (grade level)

4 data collection tools (data collection tool type)

5 working process (duration of study, sample size, variables)

6 data analysis

7 conclusion (future research, teachers and practitioners).

3.6 Data analysis, validity and reliability

Articles compiled using the publication classification form were analysed using the content analysis method, and the data were processed into an MS Excel 2016 worksheet. While the articles were being classified, a separate data record was created for each form heading. In order to ensure the reliability of the research, the authors carried out the process together at all steps. The resulting differences of opinion were resolved to reach joint decisions. In this way, the internal validity and reliability of the study were ensured. The data up to the conclusions and recommendations of the articles were analysed by descriptive analysis (frequency, percentage). The results and recommendations of the articles were examined under three main headings, namely, suggestions for future researchers, teachers and robotic practitioners. The data was transferred to the NVIVO 12 program, and content analysis was conducted. The data obtained is presented as tables, graphs and concept maps.

3.7 Findings

The findings of the 45 studies examined with S.L.R. were compiled as the years of the studies, the countries where the implementations took place, the coding approach used in the activities, the methods of the studies, the educational level of the sample, the data collection tools, the duration of the study, the size of the sample, the variables, the approaches used in the analysis of the data, the results and recommendations of the studies.

3.8 Distribution of studies by country

When coding activities in ECE are analysed by country, it is noticeable that most studies were conducted in Turkey (n = 10). As can be seen in Figure 3, the USA (n = 9), Spain (n = 7) and China (n = 5) were mainly analysed. The fewest studies were conducted in Korea, the Netherlands, Israel, the UK, Uruguay, Taiwan, Cyprus, Greece, Japan, Japan, Portugal and Portugal, with one publication each.

3.9 Distribution of studies by year

When the distribution of coding activities carried out in early childhood according to years is examined, it is seen that there is an increasing trend. When Figure 4 is examined, it is understood that studies were carried out in 2019 (n = 6), 2020 (n = 10), 2021 (n = 8) and 2022 (n = 21).

Figure 3 Distribution of studies by country (see online version for colours)

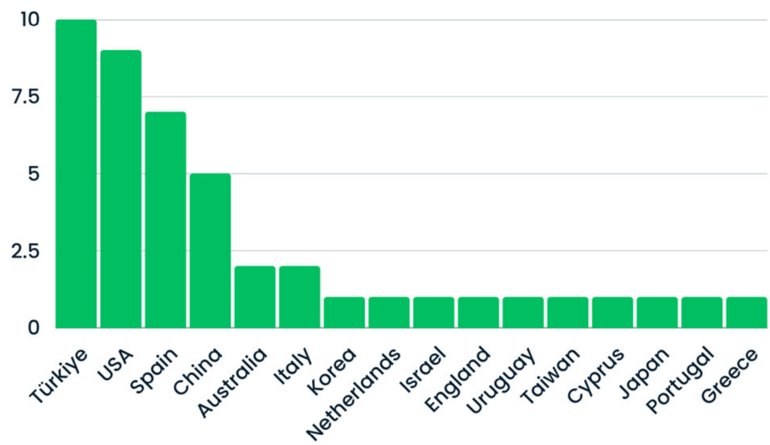
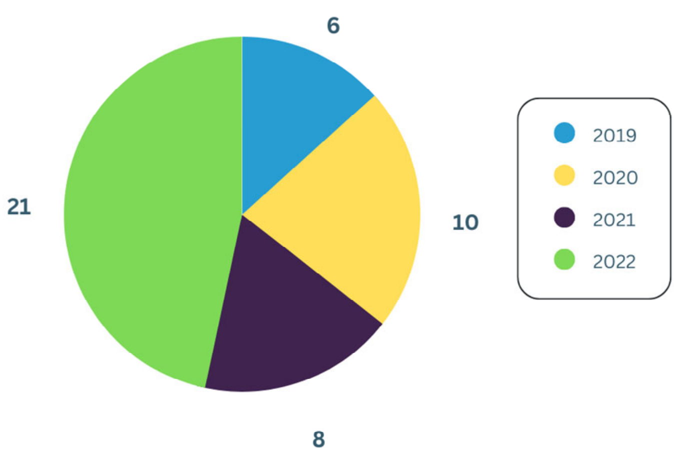


Figure 4 Distribution of studies by year (see online version for colours)



3.10 Methods of studies

When the coding studies in early childhood in Table 2 were examined, it was seen that most of the studies were conducted in the semi-experimental design (n = 24, 53.33%), which is one of the quantitative research methods. Among qualitative (n = 11, 24.44%) research methods, case study (n = 9, 20%) and mixed methods research, triangulation model (n = 10, 22.2%) were preferred the most.

Table 3 Research methodologies

Research methodologies		*Research methods*	*f*	*%*
Quantitative	Experimental	Semi-experimental	24	53.33
Qualitative		Case study	9	20
		Phenomenology	1	2.22
		Design based research	1	2.22
Mixed		Triangulation	10	22.2
Total			45	100

When analysed according to the age group of the sample, it was seen that qualitative research methods were not used at all in grades K1–K3 in primary school students. The qualitative research method was used only in the kindergarten sample. The qualitative research method was predominantly preferred in kindergarten.

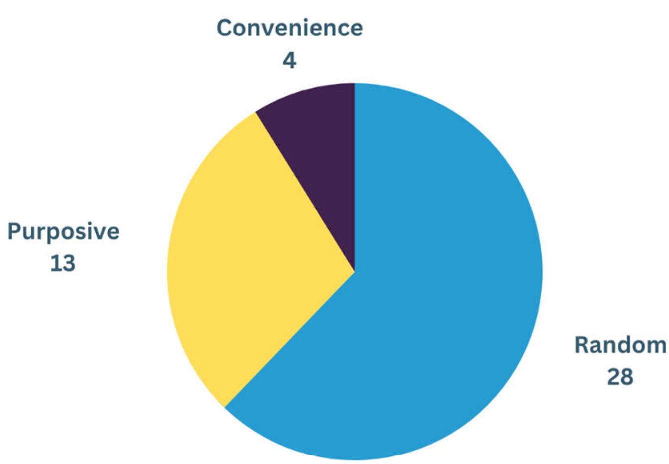
Table 4 Research methods according to the sample level

	Qual	*Quan*	*Mixed*	*f*	*%*
Kindergarten	11	17	5	33	73,3
Primary	-	7	5	12	26,7

3.11 Sample selection method

According to the sample selection method, it was observed that the random sampling method was primarily used in the studies (n = 28), followed by purposive sampling (n = 13). Convenience sampling is the least preferred sample selection method (n = 4).

Figure 5 Sample selection method (see online version for colours)



3.12 Sample type, data collection tools according to research method

When it is analysed which research method and which data collection tools were used according to the type of the sample, it is seen that tests were used the most (n = 25). Then, video and audio recordings and observation forms are the most frequently used data collection tools.

Table 5 Sample Type, data collection tools according to research methodology

		O.F.	*I.F.*	*M.*	*Tests*	*Scale*	*S. W.*	*Others*	*Total (f)*
PreS.	Quantitative	2	-	-	13	3	-	1	19
	Qualitative	5	1	8	-	-	2	2	18
	Mixed	1	4	2	2	-	1	3	13
Pri.	Quantitative	1	1	4	7	-	-	-	13
	Qualitative	-	-	-	-	-	-	-	-
	Mixed	3	3	1	3	-	2	2	14
Total		12	9	15	25	3	5	8	77

Notes: *O.F = observation form, I.F = interview form, M = multimedia records, S.W = student's worksheet.

3.13 Implementation duration

When the duration of the interventions in the preschool group is analysed, it is understood that the interventions were mainly realised as interventions lasting one month or less (n = 17) or, although less frequently, they lasted longer than two months, approximately as long as a school term (n = 13).

Table 6 Implementation duration

	Short than one month	*Medium long than one month*	*Long than two months*	*f*	*%*
Kindergarten	17	3	13	33	73.3
Primary	4	2	6	12	26.7
Toplam	21	5	19	45	100

In primary school, it is seen that coding activities are generally carried out in studies lasting more than two months (n = 6) and one month or less (n = 4), although less than that (Table 6).

3.14 Sample size

When the sample sizes are analysed according to the sample level, it is seen that the study groups in the range of 31–100 (n = 19) are primarily examined in the studies (Table 7).

Table 7 Sample size

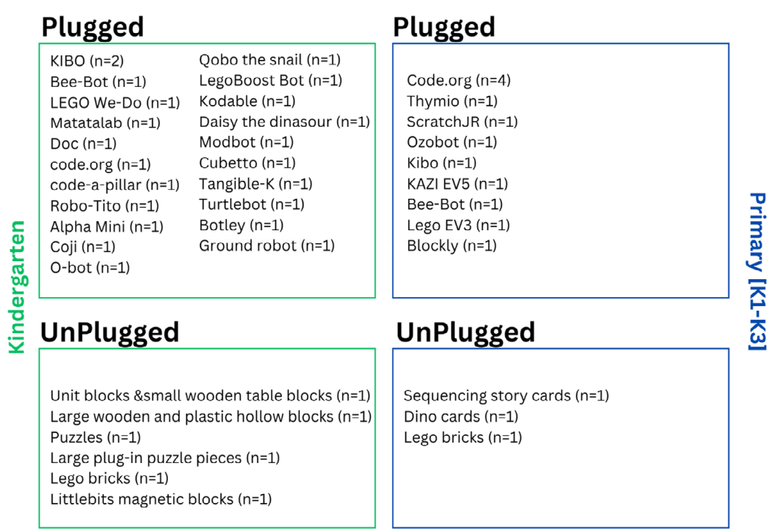
	1–10	*11–30*	*31–100*	*101–300*	*301–1,000*	*f*	*%*
Kindergarten	2	12	14	5	-	33	73.3
Primary	-	3	5	3	1	12	26.7
Toplam	2	15	19	8	1	45	100

3.15 Sample group with the robotic tool used

When the coding activities tools used in preschool and primary school were categorised, the tools were classified as plugged and unplugged. In the preschool and primary school groups, blocks made of plastic or wood and Lego bricks were mainly used. In addition, story cards and puzzles were also used to create sequencing and storytelling for CT and algorithms.

For plugged activities, robotic applications such as Bee-Bot, KIBO, Ozobot and Lego We-Do, which are generally suitable for early age groups due to their interfaces for visual programming, were selected and included in the studies according to their costs. At the same time, web-based coding activities such as code.org and Daisy the Dinosaur were also used (Figure 6).

Figure 6 The robotic tool used (see online version for colours)



3.16 Variables

When the variables in the studies are examined, it is seen that they are grouped under five headings: CT, 21st-century skills, Math, Social and Emotional and Other variables. When evaluated together with the results of the studies, it is understood that studies on computational thinking were predominantly conducted (n = 24) and that these interventions also improved skills such as coding (n = 9), sequencing and problem-solving in children. Among 21st century skills, creativity (n = 8) and communication (n = 7) skills developed the most. In mathematics, it is understood that three-dimensional rotation, spatial reasoning, and fluency skills have also developed. Under the social-emotional heading, expressing and managing emotions/self-expression and social behaviour skills were practised, and students improved these skills. Under the other heading, it is seen that there are studies on the development of children's technology use skills, engineering and design skills, and their career choices are also positively affected (Figure 7).

Figure 7 Variables (see online version for colours)

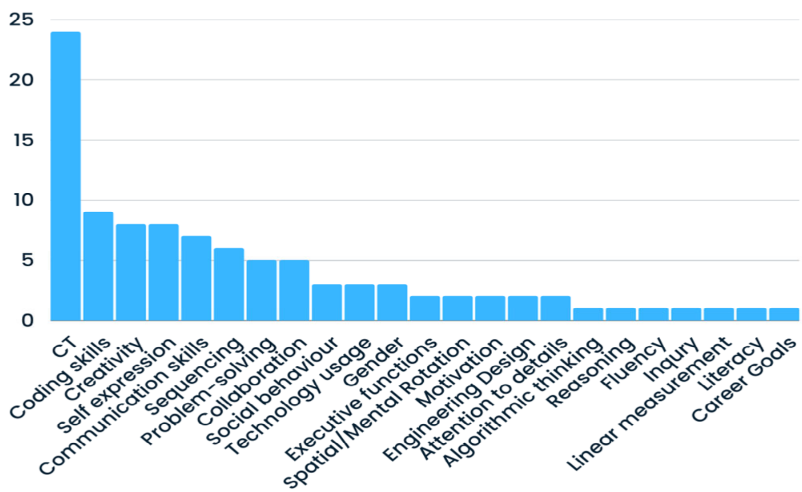
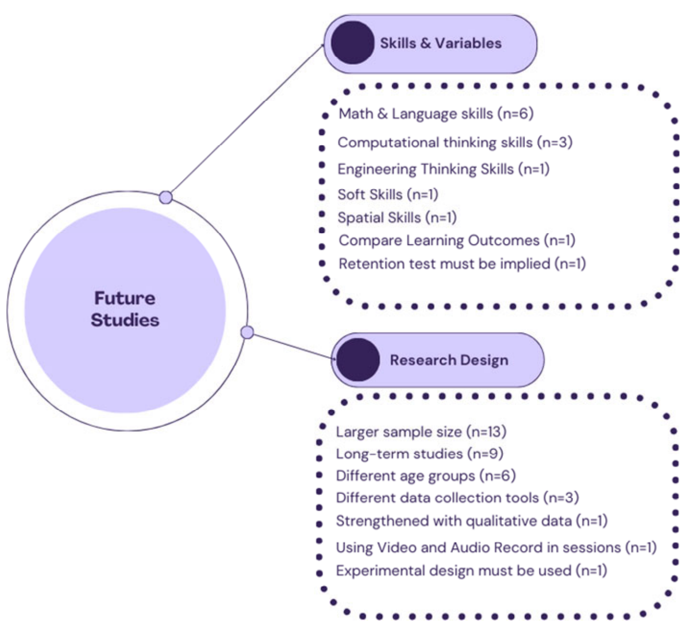


Figure 8 Suggestions for future research (see online version for colours)



3.17 Suggestions for future research

In the 45 studies conducted, it is seen that the authors' suggestions are shaped under two main headings: skills and variables and research design. Under the heading of skills and variables, examining the development of mathematics and language skills (n = 6) and examining CT skills and their subheadings (n = 3) are among the commonly expressed suggestions. Engineering design skills, soft skills, comparing learning outcomes, studying spatial skills and conducting retention tests after the applications are also suggested.

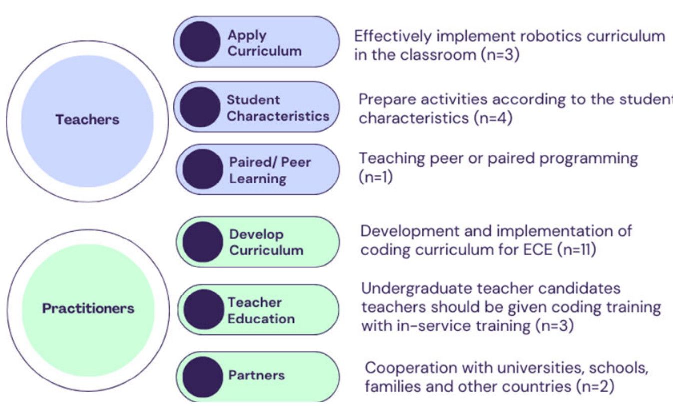
Regarding research design, it was suggested that it is crucial to work with larger samples to generalise the study results (n = 13). It was also frequently emphasised that studies should include more activities and that longer-term instructional interventions should be planned (n = 9) (Figure 8).

3.18 Recommendations for teachers and practitioners

In this process, it was emphasised that teachers should include coding and robotic activities that they choose according to their students' prior knowledge, the goals and outcomes expected to be developed, and the age groups of their students (n = 4) in the learning environments in the classroom (n = 3). It was also suggested that paired or peer learning approaches could be used in programming instruction so that students can gain more accessible and more effective programming experiences through communication and collaboration (n = 1).

When the suggestions of the studies for practitioners, policymakers and administrators are analysed, it is seen that the most emphasised suggestion is the development and implementation of a robotics and coding curriculum in schools in ECE (n = 11). At the same time, it is also recommended to provide training on robotics and coding to pre-service teachers at the undergraduate level and teachers through in-service training and to organise training to develop activities and course content (n = 4). It was also suggested that universities, schools, families and international organisations should cooperate and international projects should be implemented in schools (n = 1). For younger children, it was suggested that families should be involved to support students' learning processes (n = 1).

Figure 9 Recommendations for teachers and practitioners (see online version for colours)



4 Discussion

This systematic review was conducted to provide an overview of the research literature on coding activities in early childhood. Although coding activities are a new topic in early childhood, they can provide insights into the current status and directions for future research. Based on the results and suggestions of the studies included in the review, it was aimed to design interventions that can be carried out according to the children's characteristics, prior knowledge and the skills to be developed and to understand the possible results. The study includes which skills are developed in children between 3 and 8 who receive coding education and suggestions for implementation.

In the past decade, there has been a rapid increase in ECE for the introduction of programming and the development of CT skills (Chou, 2020; Critten et al., 2022; Gerosa et al., 2022; Qu and Fok, 2022). Studies often use non-computerised coding activities such as storyboards, puzzles, or LEGO bricks (Akpinar and Akgunduz, 2022; Aksoy and Aksoy, 2022; Kewalramani et al., 2020) or robotics and screen-based visual programming technologies (Chaldi and Mantzanidou, 2021; Pila et al., 2019; Urlings et al., 2019) because the age group is small and not yet literate. The studies included in this SLR study also show that early coding is appropriate and beneficial (Macrides et al., 2022; Sullivan and Umashi Bers, 2019). Learning to code using developmentally appropriate technologies and strategies for young learners fosters creativity, collaboration, communication and creating new content. Teaching coding to preschool children in early primary school has shown positive results (Sulistyaningtyas et al., 2021). Today, it is essential for families, schools, teachers and policymakers to provide environments where children can use these skills to develop their digital skills and participate in a productive position at an early age intertwined with technology (Critten et al., 2022).

It is seen that the highest number of publications was realised in 2022 and has shown an increasing continuity in recent years. Turkey and the USA have the highest number of studies in this field. As a reflection of America's focus on STEM, coding and robotics education as a reflection of no child left behind in 2001 and every student succeeds act (ESSA) policies in 2015, it is understood that coding education is also emphasised in early childhood (Güneş, 2021).

It was determined that the studies, mainly in K1–K3 grades within the scope of early childhood, were generally conducted in a quasi-experimental design from quantitative methods. These studies showed that coding studies were more effective in children's problem-solving and creativity skills than pencil and paper tests (Çakır et al., 2021). In addition, coding education is beneficial in developing engineering design skills, project management, sequencing and programming skills in children aged 4–7 years (Kazakoff and Bers, 2014; Pérez-Marín et al., 2022). Children can grasp simple programming concepts using concrete, screen-based or hybrid teaching environments (Macrides et al., 2022). According to the sample selection method, random sampling was used the most in the studies (n = 28), followed by purposive sampling (n = 13). Convenience sampling is the least preferred sample selection method (n = 4). This finding differs from Gunes and Kucuk's (2022) finding that purposive sampling is the most popular sample selection method in educational robotics studies, and random sampling is the least popular. This situation can be considered as the characteristics of the sample's age group and the application's purpose affect the researchers' decisions regarding the sample selection method. When it is analysed which research method and which data collection tools were used according to the type of the sample, it is seen that tests were used the most (n = 25). Then, video and audio recordings and observation forms were among the most frequently used data collection tools.

When the implementation periods were examined in the preschool group, it was determined that the implementations were mainly carried out for one month or less (n = 17). A few studies showed that the implementations lasted approximately one school term (n = 13). In primary school, it was determined that studies lasting more than two months (n = 6), usually one school semester, were conducted. In addition, in a few studies, coding activities were carried out for one month or less (n = 4). When the sample sizes according to the sample level are examined, it is seen that the study groups in the range of 31–100 (n = 19) are primarily examined in the studies. The findings regarding study times and sample sizes are similar to the results of the systematic review on coding and educational robotics in the literature (Gunes and Kucuk, 2022). In addition, task-based scales and rubrics, among the most preferred data collection tools in early childhood practices, are similar to the literature (Macrides et al., 2022).

When the coding activities tools used in preschool and primary school were categorised, the tools were classified as plugged and unplugged. In the preschool and primary school groups, blocks made of plastic or wood and Lego bricks were mainly used (Canbeldek and Isikoglu, 2023; Xu et al., 2021). Story cards and puzzles were also used to create sequencing and storytelling for CT and algorithms (Saxena et al. 2020). For plugged activities, robotic applications such as Bee-Bot, KIBO, Ozobot and Lego We-Do, which are generally suitable for early age groups due to their interfaces for visual programming, were selected and included in the studies according to their costs (Çakır et al., 2021; Egbert et al., 2021; Socratous and Ioannou, 2021). At the same time, web-based coding activities such as code.org and Daisy the Dinosaur were also used (Pila et al., 2019; Tran, 2019; Turan and Aydoğdu, 2020). According to Batı (2022), while unplugged coding activities are more prominent in early childhood, both methods positively affect children. Teachers need to decide which method to choose based on children's age, prior knowledge level and the activity's goals, and to get the support of parents in the process.

When the results of the studies are examined, it is noticeable that there are cognitive developments in children, especially in CT skills and their sub-dimensions, such as algorithmic thinking, sequencing, and debugging (Merino-Armero et al., 2022; Yang et al., 2022). In addition, social skills learning, development of language skills, mathematical skills and technological literacy have also increased (Gunes and Kucuk, 2022; Somuncu and Atasoy, 2022). This is similar to the results in the literature. In addition, teaching coding early makes it easier for students to concretise abstract concepts such as numbers, size and shape in mathematics. It is beneficial in developing language skills and visual memory. Coding education and robotics activities at an early age can positively contribute to children's cognitive, social and emotional development and benefit them (Wang et al., 2022).

In this SLR study, the use of CT, creativity, coding skills and social skills as variables and the development of these skills is a result in line with the literature. It has been observed that coding education and robotics activities in ECE are beneficial for developing students' reasoning, CT and language skills. For this reason, studies recommend policymakers, practitioners, and administrators include coding and robotics programs in the curriculum in early childhood schools (Deniz et al., 2022; Hassenfeld et al., 2020; Pinto et al., 2022; Zviel-Girshin et al., 2020). It is emphasised that teachers should organise coding and robotics activities according to students' prior knowledge, interest and skill level. In order to realise this, teachers must first have these skills.

For this reason, it is also recommended to provide training on robotics and coding to pre-service teachers at the undergraduate level and in-service training and to organise courses to develop activities and course content (Çakır et al., 2021; Yang et al., 2022; Zviel-Girshin et al., 2020). It is also recommended that schools, universities and international organisations work together and provide the necessary financial and scientific support for implementing international projects and frameworks in the coding field in schools (Deniz et al. 2022). It is also emphasised that families should cooperation with schools and administrations in order for students to understand the outcomes and maintain their permanence, contribute to the process by supporting teachers, and continue activities for these skills at home (Critten et al. 2022). Teachers were recommended to select, implement and evaluate the effects of coding and robotics activities with classroom activities selected according to the levels of their students (Çakır et al. 2021; Metin, 2022; Pérez-Marín et al., 2022; Turan and Aydoğdu, 2020; Yao et al., 2022; Zviel-Girshin et al., 2020). There is no difference between students in terms of gender (Bati, 2022; Pila et al., 2019; Zviel-Girshin et al., 2020). Providing coding education to all children at an early age may be beneficial for women to choose engineering as a career choice and play a role in meeting the increasing need for the labour force (Sullivan and Umashi Bers 2019), contrary to what is emphasised in the literature in engineering fields in the following years (Varma, 2010). It is also vital that visual programming and unplugged coding activities are selected by students' age level, prior knowledge and interests (Bati, 2022). In addition, since robotic technologies can be costly, receiving financial support from projects or administrators can benefit researchers.

Since coding education in early childhood is still an emerging field, conducting more research and increasing the number of experimental studies in this field may be recommended. It is recommended that policymakers create curricula that include plugged and unplugged activities for coding and CT skills with proven effectiveness and efficiency. It is essential that these curricula are compulsory in schools and that teachers are supported with undergraduate and in-service training to support the development of these skills more accurately. In addition, since the age groups of children are small, it may be beneficial for the development of their children as a whole if families are also a partner in this process. Planning future studies so families are included and planning them so that longer-term practices are carried out may be more effective in developing and permanence the targeted skills.

5 Patents

This section is not mandatory but may be added if patents result from the work reported in this manuscript.

Author contributions

Conceptualisation, M.U., H.G. and H.U.; methodology, M.U., H.G. and H.U.; validation, M.U., H.G., H.U., S.P. and M.K.; formal analysis, M.U., H.G., H.U., S.P. and M.K.; investigation, M.U., H.G., H.U., S.P. and M.K.; writing – original draft preparation, M.U., H.G. and H.U.; writing – review and editing, S.P.; visualisation, M.U., H.G., H.U., S.P. and M.K.; supervision, S.P., M.K.; project administration, M.U., S.P. and M.K. All authors have read and agreed to the published version of the manuscript.

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Appendix A

Articles included in S.L.R.

Author(s) and year	*Country*	*Sample*	*Variables*	*Method*	*Coding tools*	*Result*	*Recommendations*	*Database*
1 Akpinar and Akgunduz (2022)	Türkiye	Kindergarten	• Career goals • Perceptions of Engineering	Qual	Unplugged	• Positive effects on students' career planning • Increased students' interest • Students' product design/invention goal process	• Update the preschool curriculum regarding STEM education and especially engineering-based activities • Use different block-play materials (short-long term) • Use other scales and evaluation techniques (e.g. the three mountain problem by Piaget and false-belief test)	Springer
2 Aksoy, and Aksoy (2022)	Türkiye	Kindergarten	• Creativity • Attention to details • Acceptance of differences • Fluency • Originality	Quan	Unplugged	• All variables were found to be significantly different for the experiment group		Taylor & Francis
3 Arfé et al. (2020)	Italy	Primary school (5–6 old)	• Coding skills • Executive functions	Quan	Code.org	• Practising code.org activities improve coding skills executive functions studies would be important	• Cross-sectional and long-term studies	Elsevier
4 Bers et al. (2019)	Spain	Kindergarten (3–5)	• Coding • C.T.	Mixed	KIBO	• Coding can be taught for three years • The strategies used promoted communication, collaboration and creativity in the classroom settings	• Öğretmenler kodlama müfredatını bireysel olarak uyarlamalı-uygulamalı • Cross-cultural and cross-subject studies should be implemented • Comparisons of learning outcomes	Elsevier

Articles included in S.L.R. (continued)

	Author(s) and year	*Country*	*Sample*	*Variables*	*Method*	*Coding tools*	*Result*	*Recommendations*	*Database*
5	Brainin et al. (2022)	Israel	Kindergarten (5–7)	• Spatial relations • Visual-memory • Mental rotation	Quan	Bee-Bot	• No effect	• Further studies must focus on spatial or other cognitive abilities, such as mathematical or verbal skills	Taylor & Francis
6	Cakir et al. (2021)	Türkiye	Kindergarten	• Problem-solving • Creativity	Quan	LEGO We-Do	• Problem-solving skills improved • Imagination and originality factors in the language and drawing were found to be statistically significant	• Other soft skills must be studied • Robotics curriculum must be integrated E.C.E. program	Elsevier
7	Canbeldek and Isikoglu (2023)	Türkiye	Kindergarten	• Cognitive development skills • Language development • Creativity	Quan	Unplugged Matatalab Bee-Bot Doc	• Positively affects children's cognitive development skills, language development and creativity	• Larger sample size • Other socio-emotional skills must be studied	Springer
8	Chaldi and Mantzanidou (2021)	Greece	Kindergarten	• Programming • Communication skills • Teamwork • Algorithmic thinking	Qual	Bee-Bot	• Programming, algorithmic thinking • Vocabulary and communication skills developed	• Larger sample size	Springer
9	Chevalier et al (2020)	Switzerland	Primary school (Grade 3)	• CT competence progress • Programming behaviours • C.T. competence factors	Quan	Thymio	• Programming promotes trial-and-error learning, enhances cognitive processes, and aids effective problem-solving	• Larger sample size • Teacher opinion • Long-term studies	Springer
10	Chou (2020)	Taiwan	Primary school (Grade 3)	• C.T. competence	Mixed	ScratchJR	• The students exhibited high retention of C.T. competence one month after completion • Parental involvement causes retention	• Larger sample size • Deney-kontrol gruplu çalışılabilir	Sage

Articles included in S.L.R. (continued)

	Author(s) and year	*Country*	*Sample*	*Variables*	*Method*	*Coding tools*	*Result*	*Recommendations*	*Database*
11	Ciftci and Bildiren (2020)	Türkiye	Kindergarten (4–5 years)	• Problem-solving skills • Non-verbal cognitive abilities	Quan	code.org	• No effect on problem-solving skills • Positive effect on non-verbal cognitive skills	• Studies should be made using different robotic tools • Experiment-control group ages should be equal	Taylor & Francis
12	Clarke-Midura et al. (2021)	USA	Kindergarten	• Reference frames	Qual	Code-a-pillar	• ProtoAllocentric to ProtoEgocentric was the most common reference frame, indicating an imprecise shift from object-object to subject-object reference frames	• Future research should investigate whether or not children's use of and shifts within reference frames leads to more successful programming • Researchers could also investigate how children engage in reference frameshifts when they have more coding experience or engage in more complex coding sequences or practices, such as loops or functions	Elsevier
13	Critten et al (2022)	UK	Kindergarten (2–4 years)	• C.T. • Collaboration • Communication	Qual	Bee-Bot	• C.T. skills, collaboration, logical thinking and debugging algorithms were enhanced	• Children must have been supported by their families if robot tasks are so complex for kids	Springer
14	Çakır et al (2021	Türkiye	Kindergarten	• Problem-solving skills • Creative thinking	Quan	Lego We-DO	• Robotics enhanced problem-solving skills compared to pen-and-paper activities	• In-service training programs should be held to support E.C.E. teachers	ScienceDirect
15	del Olmo-Munoz et al. (2020)	Spain	Primary school	• C.T. skill • Motivation • Gender	Quan	Code.org	• Unplugged activities enhance C.T., motivation and gender.	• Using a mixed approach to use both plugged and unplugged activities • Larger sample size • Long-term studies with more activities	ScienceDirect
16	del Olmo-Munoz et al. (2022)	Spain	Primary school	• C.T. skill • Motivation	Quan	Code.org myclassgame World Map Builder Genially	• The gamification techniques can be effective in improving • C.T. skills	• Third group (traditional class setting) can be added to compare which method is effective	Google Scholar

Articles included in S.L.R. (continued)

	Author(s) and year	*Country*	*Sample*	*Variables*	*Method*	*Coding tools*	*Result*	*Recommendations*	*Database*
17	Deniz et al. (2022)	Türkiye	Primary school	• Communication • Group communication • Collaboration • Expressing emotions • Self-expression • Cooperation • Coping with challenges • Strategising • Following instructions • Achieving a goal • Managing emotion control	Quan	Dino card	• The children in Turkey have the highest average, and the children in Italy have the lowest average in the "non-robotic activity" application • The "robotic activity" application determined that the children in Italy had the highest average, while those in Spain and Lithuania had the lowest average. • The average score difference between robotic and non-robotic activity groups is highest in Italy for the robotic activity group and the lowest in Spain and Lithuania	• Robotics curriculum must be integrated E.C.E. program • International network professionals and organisations can work closely with academia, educational institutions, and teachers • PEARL Education Model, teacher guidance can be provided	Sage
18	Egbert et al. (2021)	Italy	Primary school	*Coding skills	Mixed	Ozobot	• Teachers need support when implementing coding in classrooms. Emphasising content and process, especially problem-solving, is effective for young children. Robots and well-designed coding tasks boost engagement. Data from multiple sources, including teachers and students, is crucial for understanding classroom coding	• Different measurement tools should be used • Long-term studies with more activities • Gender differences must be studied	ScienceDirect
19	Gerosa et al. (2022)	Lithuania	Kindergarten	*CT	Quan	Robo-Tito	• High attention, motivation and participation in the activity the intervention worked on the children	• Students should be given individual tasks before and after the activity	Google Scholar
20	Hassanfeld et al (2020)	Spain	Primary school	*Literacy	Quan	Kibo	• There is a positive relationship between literacy and programming skills	• Coding as Literacy (CAL) yaklaşımı okul öncesinde benimsenmeli	Google Scholar

Articles included in S.L.R. (continued)

	Author(s) and year	*Country*	*Sample*	*Variables*	*Method*	*Coding tools*	*Result*	*Recommendations*	*Database*
21	Kewalramani et al (2020)	USA	Kindergarten	• Creativity • Inquiry • Engineering design thinking	Qual	Littlebits magnetic blocks	• STEM-focused playful experiences integrate scientific inquiry, design thinking, creativity, and interdisciplinary STEM vocabulary for children	• Engineering habits of mind, creativity and inquiry dispositions should now be taken into account	Google Scholar
22	Kewalramani et al (2021)	Uruguay	Kindergarten	• Social competencies • Emotional competences	Qual	Alpha mini Coji Qobo, the snail LegoBoost Bot	• In parent-child-robot, robot-child, and child-sibling interactions, a new multimodal environment fosters children's social and emotional learning, including communication, gestures, and empathy expression	• Larger sample size	Sage
23	Lennon et al. (2022)	U.S.A.	Kindergarten	• Social behaviour • Independent behaviour	Qual	Kodable Daisy the dinosaur	• Daisy game contributed more to their coding skills because, according to Kodable, students found it more interesting	• The impact of game types can be looked at	ScienceDirect
24	Liu et al. (2023)	Australia	Kindergarten	• Knowledge level	Mixed	Modbot	• Engage hands-on learning to teach basic underwater concepts. • Use water environments as exciting learning settings. • Provide distinctive visualisations for different functions. • Incorporate more mechanical and bionic modules. • Enable emotionally intelligent interactions	• Long-term studies • Robot parts can be organised for the student • It can be studied with experimental methods • Larger sample size	Springer

Articles included in S.L.R. (continued)

	Author(s) and year	*Country*	*Sample*	*Variables*	*Method*	*Coding tools*	*Result*	*Recommendations*	*Database*
25	Metin (2022)	Australia	Kindergarten	• Basic robotic skills • Robotic coding skills	Quan	Cubetto	• The results showed that activity-based unplugged coding enhanced this group of Preschoolers' basic coding and robotic coding skills	• Larger sample size • Long-term studies • Choosing activities for children • Paired or group programming teaching • It should be added to the curriculum	Springer
26	Pinto et al. (2022)	USA	Kindergarten	• Communication • Collaboration • Community building • Content creation • Creativity	Qual	Kibo	• Students showed progress in all dimensions, which are the steps of the 6C model	• Long-term studies • It should be added to the curriculum	Google Scholar
27	Muñoz-Repiso et al (2020)	China	Kindergarten	• Programming skills • C.T. • Sequencing algorithms • Debugging	Quan	Tangible-K	• Progress was seen in all three dimensions of computational thinking: sequences (algorithms), action-instruction correspondence and debugging	• Larger sample size	Google Scholar
28	Nam et al. (2019)	Türkiye	Kindergarten	• C.T. • Sıralama (sequencing) • problem çözme	Quan	Turtlebot	• Students' better problem-solving and sequencing skills compared to the control group	• It should be added to the curriculum	Springer

Articles included in S.L.R. (continued)

	Author(s) and year	*Country*	*Sample*	*Variables*	*Method*	*Coding tools*	*Result*	*Recommendations*	*Database*
29	Pérez-Marín et al (2022)	Portugal	Kindergarten	• Sequencing	Quan	Cubetto	• Sequencing and route drawing skills improved	• Activities should be selected following the child's age and the readiness of his/her prior knowledge • Video and audio recordings can be taken • It can be tested in different schools • The effect of variables such as cycles and control structures on the development of mathematics, language and social interaction skills can be examined	Taylor & Francis
30	Pila et al. (2019)	Spain	Kindergarten	• Coding skill	Mixed	Daisy the dinosaur Kodable	• The game's appearance is important for the students, but this does not make a difference in gender • As a result, it was understood that students could learn basic coding skills with the applications	• Future studies could be designed to examine or compare the effects of guided and unguided programming education	ScienceDirect
31	Qu et al. (2022)	Korea	Primary school	• C.T.	Mixed	KAZI EV5	• The activity ensured the development of medium and high-level skills in students	• Larger sample size • Long-term studies • It should be added to the curriculum • Variables such as age, gender, level of interest in learning, and cultural factors can be examined	Springer
32	Saxena et al. (2020)	Spain	Primary school	• C.T. • Pattern recognition • Sequencing • Algorithm design	Mixed	Bee-Bot Lego sequencing story cards	• K-2 and K3 students were more successful in creating algorithms • Unplugged and plugged activities helped to modify abstract concepts. Unplugged was particularly effective for K1	• Decomposition and debugging dimensions of computational thinking are proposed • Larger sample size	Springer

Articles included in S.L.R. (continued)

	Author(s) and year	*Country*	*Sample*	*Variables*	*Method*	*Coding tools*	*Result*	*Recommendations*	*Database*
33	Shumway et al. (2021)	U.S.A.	Kindergarten	• C.T.	Qual	Cubetto Botley	• In particular, the operations performed by the students during debugging through authentic problems facilitated the teaching of the concepts of one less and one more • The activities also contributed to students' sorting and decomposition skills	• More studies should be conducted on the relationship between mathematics and computational thinking	Taylor & Francis
34	Silvis et al. (2022)	China	Kindergarten	• C.T.	Qual	Bee-Bot Cubetto Botley	• It was found that concrete programming environments represent pedagogically important contexts for separating young children's basic technical knowledge from more abstract programming knowledge	• More work should be done on children's debugging skills	Google Scholar
35	Socratous and Ioannou (2021)	Japan	Primary school	• Debugging skills	Quan	Lego EV3	• Structured robotics curriculum for children both have higher contributions to the development of debugging skills, and unstructured curriculum has higher contributions to lesson participation. *Teachers should use these two approaches together in robotics teaching	• Larger sample size • Different age groups • Experimental design	Springer
36	Somuncu and Aslan (2022)	USA	Kindergarten	• Mathematics reasoning skill	Quan	Bee-Bot	• Improved mathematical reasoning skills in favour of the experimental group	• Cross-cultural • Applying a retention test • Teachers can be recommended to prepare and implement such activities in the classroom • The effect on reasoning skills in mathematics can be investigated • studies can be strengthened with qualitative data	Springer
37	Terroba et al. (2022)	U.S.A.	Kindergarten	• C.T.	Mixed	ground robot	• Computational thinking in early childhood, the use of ground robots for the development of skills is effective	-	Taylor & Francis

Articles included in S.L.R. (continued)

	Author(s) and year	*Country*	*Sample*	*Variables*	*Method*	*Coding tools*	*Result*	*Recommendations*	*Database*
38	Tran (2019)	Cyprus	Primary school	• C.T.	Mixed	Blockly code.org	• Coding and computational thinking skills benefit real-life applications and foster soft skill development like collaboration, creativity, abstraction, and persistence	• Different data collection tools • Teachers should be developed	Sage
39	Turan and Aydoğdu (2020)	Türkiye	Kindergarten	• Scientific process skills	Quan	code.org o-bot	• Robotic coding education, applied to preschool children, developed the children's skills in scientific processes	• Different age groups • Different learning areas • Teachers should do classroom activities	Springer
40	Urlings et al. (2019)	Spain	Kindergarten	• Executive functioning skills	Quan	Bee-Bot	• Enhanced memory, non-verbal ability, verbal fluency and planning ability of kindergarteners	• Larger sample size • Different age groups	Taylor & Francis
41	Wang et al. (2022)	USA	Kindergarten	• C • C.T. • Intelligence	Quan	Matatalab	• The results suggest that integrated cognitive control strategies based on play and social interaction can help young children learn to code efficiently and effectively. There was no significant difference between the groups	• Larger sample size • The socio-economic status of the family should also be studied • The cognitive control strategies integrated into the experimental group might have helped young children process the abstract information involved in the loop and algorithm dimensions	Taylor & Francis
42	Welch et al. (2022)	Türkiye	Kindergarten	• Linear measurement • C.T.	Qual	Cubetto	• The social context, gestures, and verbal descriptions influenced children's understanding of a dynamic linear unit	• A larger analysis of children engaging with other tangible coding toys • How coding toys can • be used as a unique and meaningful context to build children's mathematics knowledge and skills	Google Scholar

Articles included in S.L.R. (continued)

	Author(s) and year	*Country*	*Sample*	*Variables*	*Method*	*Coding tools*	*Result*	*Recommendations*	*Database*
43	Xu et al. (2022)	Holland	Kindergarten (5–6 years)	• Arithmetic fluency • C.T. reasoning ability • Creative thinking	Quan	Unplugged	• No significant relationship was found between reasoning and creativity skills. All other skills are interrelated	• The development of C.T. in older age groups and its relationship with other skills can be examined	ScienceDirect
44	Yang et al. (2022)	China	Kindergarten (4–5 years)	• Computational thinking • Sequencing ability • Self-regulation	Quan	Matatalab	• The study shows that robot programming has positive benefits for early childhood development, particularly in terms of computational thinking and sequencing ability, compared to traditional E.C.E. block play activities	• Teachers should learn to code • It can be added to the curriculum	Wiley
45	Zviel-Girshin et al (2020)	USA.	Kindergarten AND Primary school	• Technological thinking • Using technology confidence • 21st skills • Self-confidence	Mixed	Lego	• There is no gender difference in the desire to study robotics. Girls can solve problems and enjoy robotics activities as much as boys do	• It can be added to the curriculum • In-service teacher training should be provided	Springer