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Investigation of the effects of unplugged coding activities developed for preschool on motivation, computational thinking and problem-solving skills

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Abstract
The aim of this research was to explore the effects of unplugged coding activities on preschoolers' motivation, computational thinking and problem-solving skills. The research was conducted based on a pretest-posttest control group quasi-experimental design. The experimental phase included 69 children (33 in the experimental group, 36 in the control group) aged 5–6 and attending a preschool in Hatay province of Turkey. The children had never received any coding or robotic lessons before. In the experimental group, in addition to the standard preschool curriculum, electronic material-based unplugged coding activities were carried out for one hour per week over eight weeks. The coding activities were developed by researchers. No intervention was made for the control group. To assess the effects of unplugged coding activities on children before and after the experiment, the *Motivation Scale*, *Computational Thinking Skills Test*, and *Problem-Solving Skills Scale* were used. The study revealed that children in the experimental group exhibited a significant increase in intrinsic motivation, computational thinking and problem-solving skills. This increase resulted in a meaningful difference in favor of the experimental group in comparisons between groups. The results demonstrate that unplugged coding activities in the preschool period are an effective method for supporting children's affective and cognitive development. In this regard, it is recommended that such activities be systematically and structurally integrated into the preschool education curriculum.

Keywords Preschool education · Unplugged coding activities · Motivation · Computational thinking · Problem-solving skills · Skill development in preschool children

Extended author information available on the last page of the article

1 Introduction

The importance of computational thinking (CT) and problem-solving skills in solving complex problems and analyzing big data is increasingly recognized (Akçay, 2019; Bers, 2020; Chun & Park, 2020; Jaokar, 2013; Kale & Yuan, 2021; Karayol & Temel, 2018; Oğuz & Akyol, 2015). Recently, there is a growing international consensus that children should begin developing these skills during preschool (European Schoolnet, 2015; Sun et al., 2024a). These abilities are critical for children to more easily adapt to technological developments and innovations (ISTE, 2011; Kale & Yuan, 2021). Research highlights the importance of unplugged coding activities in imparting these skills to children (Faber et al., 2017; Gaio, 2018; Lee & Junoh, 2019; Zhang et al., 2024).

Unplugged coding is a versatile problem-solving process (Zhang et al., 2024). It offers children the opportunity to encounter numerous tangible problems with differing structures (Sun et al., 2024a). Through these activities, children can engage in exploration, gain hands-on experience, communicate, and interact (Saygıner & Tüzün, 2023a). Additionally, the game-based nature of coding can increase children's motivation (Murcia et al., 2024). A motivated child is more likely to put in more effort to solve a problem or tend to find alternative solutions. Furthermore, CT processes can help children analyze problems more systematically. Therefore, motivation, CT and problem-solving skills can be considered interrelated and mutually influential variables in this process. Unplugged coding shapes the interaction and change among these three variables. This suggests that children can increase their motivation, develop more effective CT strategies, and strengthen their problem-solving skills through unplugged coding activities. In other words, unplugged coding activities nurture essential skills like CT and problem-solving and help preschool children become individuals equipped to thrive in the modern era.

Studies emphasize that introducing children to coding education at an early age can have lifelong positive impacts (Margolis, 2017; Murcia et al., 2024). Sun et al. (2022) found that children who started learning to code in the second grade of primary school demonstrated the highest computational thinking skills compared to their peers in upper grades. Despite the clear importance of early coding education, research focusing on the preschool period remains limited (Canbeldek & Işıkoğlu, 2023; Cortina, 2015; Gaio, 2018; Hill et al., 2015; Macrides et al., 2022; Su et al., 2023; Sun et al., 2024a). Most studies have predominantly focused on upper grades in primary school (Sun & Liu, 2024b). This situation limits the understanding of the possible contributions of coding education to the cognitive, emotional, and behavioral development of preschool children. To address this gap, this study aimed to reveal the effects of unplugged coding activities in the preschool period with experimental findings. The research questions focused on in the study are as follows:

RQ1. How did the electronic material-based unplugged coding activities in preschool affect children's motivation?

RQ2. How did the electronic material-based unplugged coding activities in preschool affect children's CT skills?

RQ3. How did the electronic material-based unplugged coding activities in preschool affect children's problem-solving skills?

2 Theoretical framework

2.1 Unplugged coding

Experience collaboration, interaction, exploration, curiosity, and play are fundamental in preschool (Akçay, 2019). The unplugged coding approach provides children with the opportunity to develop coding skills through game-based and experiential activities (Odaci & Uzun, 2017). This approach encourages learning through exploration (Odaci & Uzun, 2017). Instead of spending extended periods in front of a screen, it offers children an active, tangible, and enjoyable learning experience. (Alamer et al., 2015). Moreover, this approach allows children to solve problems by working together, sharing their ideas, and collaboratively designing solutions (Cortina, 2015).

Research shows that unplugged coding activities have promising results in preschool. Such activities have been shown to support children's cognitive, motor, and social skills (Lee & Junoh, 2019) and are positively received by both children and teachers (Alamer et al., 2015; Apostolellis et al., 2014; Faber et al., 2017; Klopfenstein et al., 2017). Moreover, it has been noted that these activities can be used as an alternative to digital tool-based coding (Faber et al., 2017). In fact, it is suggested that initiating coding instruction with unplugged activities may be more appropriate and effective in increasing children's awareness of coding concepts (Gaio, 2018). Saygıner and Tüzün (2023a) highlighted the importance of aligning unplugged coding activities with children's developmental characteristics to maximize their benefits.

Various unplugged coding materials have been developed for the preschool period in recent years. However, comprehensive studies on the systematic classification of these materials are limited. For instance, Erkoç (2018) referred to these materials as "technological toys", while Macrides (2022) categorized them into "programming toys" and "card games". Metin (2022), on the other hand, approached these materials as "activity-based coding". This study classified unplugged coding materials developed for the preschool period comprehensively and systematically (see Table 1).

Among these categories, electronic material-based activities hold prominence (Kanaki et al., 2025; Zurnacı & Turan, 2024). These activities involve an electronic robot navigating a tangible map and offer dynamic features such as hands-on learning experiences, interactive engagement, multimedia-supported feedback, opportunities for exploration, and flexibility for individual or collaborative work. The unique qualities of electronic-based materials, absent in the other three categories, make them especially well-suited for preschool education. Consequently, electronic-based coding was emphasized in this research, with Cubetto selected as the primary material.

Cubetto is an interactive material that aims to teach coding skills to preschool children without the need for any computer environment (Primo, 2017). This material has been developed based on the Montessori philosophy (Anzoategui et al., 2017). The material aims to establish a culture of learning through play in the classroom, with the goal of teaching coding to children aged 4–6 through interactive activities

Table 1 Unplugged coding (UC) activities in preschool

Category	Examples of coding material	Act of coding
1. UC with paper-card-based materials	Hello Ruby	Activities matching the story in the book are carried out.
	Robot Turtles, Code Monkey Island, Coder Bunnyz	Target-oriented cards are arranged step by step on the map.
2. UC with kinesthetic movement-based materials	Future Coders Robot Races, Let's Go Code, Mindware Code Hopper	Coding mats are placed in accordance with the algorithm. Then, children are encouraged to move on the mat.
3. UC with mechanical material-based	KiwiCo Robot & Coding	The mechanical robot moves on assembled puzzle pieces (tracks).
4. UC with electronic material-based	Code & Go Robot Mouse, Bee-Bot, Rumble & Bumble	The buttons on the robot are pressed in the correct sequence and number according to the algorithm.
	Botley, MagiCoders	Coding is done by pressing buttons on an external remote control.
	KUBO, KIBO, mTiny, Thames & Kosmos Coding	Blocks are arranged step by step and then each one is scanned by a barcode reader.
	Cubetto, Matatalab	The code blocks placed on the panel are detected by electronic sensors. Subsequently, a response is generated in accordance with the algorithm.

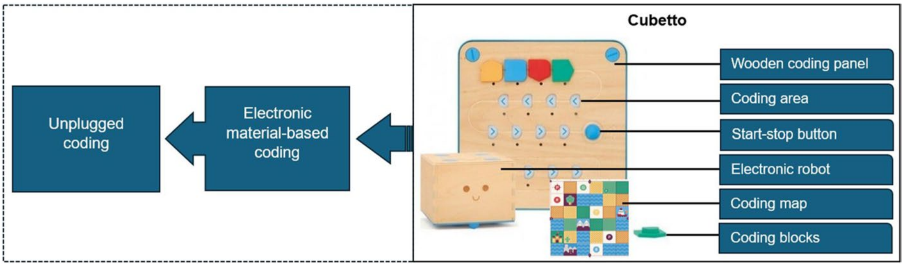


Fig. 1 Cubetto

(Primo, 2017). It is tactile, gender-neutral, screen-free, and ready to teach through play at any time (Özbey, 2018). The material consists of a wooden coding panel, coding blocks, a coding map, and a wooden electronic robot (see Fig. 1). The placement of the coding blocks on the panel dictates the movements of the electronic robot. The robot's movement direction alters based on the configuration of the colored coding blocks. The maps on which the robot moves allow task-oriented configurations. Therefore, its concrete structure, development based on a theory that aims to engage the learner actively, use of safe materials, and provision of fun content make it a strong material for teaching coding in preschool education.

2.2 Motivation

Motivation is the process of initiating, sustaining, intensifying, and making permanent the response required to reach a goal (Pintrich & Schunk, 1996). This process is shaped by internal or external factors (Carlton & Winsler, 1998). Intrinsic motivation refers to doing something out of inherent interest and enjoyment, while extrinsic motivation emphasizes doing it to achieve an external outcome (Ryan & Deci, 2000). In children, intrinsic motivation is characterized by emotions such as self-regulation, persistence, or determination that sustain behavior. In contrast, extrinsic motivation is primarily driven by external factors, with the fulfillment of expectations taking precedence (Saygıner & Tüzün, 2023b). These two motivational factors contribute to the formation of a response either separately or together (Carlton & Winsler, 1998).

Preschool period is the time when children develop basic habits or an interest in learning. Motivation is critically important during this period. Motivated children exhibit eager and determined behaviors in completing tasks, which leads them to put in more effort to develop their problem-solving skills (Heppner & Peterson, 1982). Therefore, educational activities enhancing children's motivation are crucial for their development and success.

Research emphasizes the relationship between the richness of educational environments in terms of stimuli and children's motivation (Canan, 2017; Gömleksiz & Serhatlıoğlu, 2014). Studies suggest that when children are given opportunities to make their own choices in stimulus-rich environments, their motivation tends to increase (Koyuncu, 2016). Additionally, motivation has been linked to curiosity, as highlighted by Ryan and Deci (2000). Drawing on Maslow's hierarchy of needs, Schunk (2007) suggests that maintaining motivation in learning activities depends significantly on the presence of appropriate environmental conditions.

Coding can provide children with game-based learning experience, enabling them to engage in the process more willingly and determinedly. Specifically, electronic material-based unplugged coding activities can enhance children's participation in experimental, exploratory, and active learning processes due to their manipulative features. These activities can allow children to experience flow and focus entirely on the task at hand. The research focuses on exploring evidence related to these theories.

2.3 Computational thinking skills

Although Papert's (1980) work laid the foundation for CT, the interest in this concept significantly grew following Wing's (2006) influential article. Wing (2006) defined CT as "the process of solving problems, designing systems, and understanding human behavior by applying fundamental concepts from computer science." Since then, the concept has evolved, with various definitions emerging over time (e.g., Barr

& Stephenson, 2011; Bers, 2018; Brennan & Resnick, 2012; Computing at School, 2015; Grover, 2018).

Tang et al. (2020) classified the current definitions of CT into two groups. The first group considers CT through the lens of programming and computational concepts (e.g., Brennan & Resnick, 2012; Weintrop et al., 2016). In that regard, Brennan and Resnick (2012) defined CT in children aged 8–16 using Scratch, a screen-based coding platform, and identified three components: "computational concepts, computational practices, and computational perspectives."

The second group of studies defines CT by emphasizing either domain-specific or domain-independent competencies (e.g., Bers, 2018; Selby & Woollard, 2013; Yadav et al., 2014). For instance, Bers (2018) identified seven key CT components tailored to the developmental levels of younger children: "algorithms, modularity, control structures, representation, hardware/software, design process, and debugging." Building on Bers's framework, Relkin et al. (2021) excluded the "design process" component when measuring CT in preschoolers, reasoning that questions about the design process are better Suited to qualitative assessments and are less appropriate for children aged 5–6. A similar approach was observed in the study by Masarwa et al. (2023).

The explanations suggest that the coding approach used (e.g., screen-based coding, unplugged coding), the targeted age groups, and the methods for measuring CT (e.g., tests, interviews, observations) are key factors influencing the varying definitions of CT. In this research, a CT framework consisting of six components has been developed to align with these factors (see Table 2). This framework integrates previously established CT components (Bers, 2018; Tang et al., 2020) and is designed to accommodate different age groups, measurement methods, and coding approaches. By addressing these variables, the framework seeks to resolve inconsistencies in the definition and application of CT. In the study, CT skills were assessed using these six components, and the effects of unplugged coding were analyzed within the same framework.

Table 2 CT framework

CT components:	Description:
Reasoning	Making logical deductions about events or establishing logical relationships between variables.
Algorithm	Organizing tasks in a logical sequence step by step.
Decomposition	Dividing large tasks into smaller, manageable components.
Pattern recognition	Analyzing patterns, rules, or repetitive expressions in a specific series.
Representation	Analyzing symbolic representations.
Debugging	Identifying problems/deficiencies in a task and generating solutions.

2.4 Problem-solving skills

Problem-solving is considered one of the fundamental skills for the 21 st century (Serrano-Ausejo & Marell-Olsson, 2024). Research emphasizes the importance of fostering this skill, particularly during the preschool period, to cultivate individuals with strong problem-solving abilities (Akçay, 2019; Karayol & Temel, 2018; Oğuz & Akyol, 2015). Problem-solving offers children invaluable opportunities to enhance their self-concept by learning how to address current and future challenges (Oğuz & Akyol, 2015). Through these skills, children also gain experience in recognizing and building on their own capabilities by expressing their ideas freely, overcoming daily obstacles, and supporting their learning processes (Oğuz & Akyol, 2015). These experiences not only help children adapt to life but also equip them with the ability to solve complex problems they will face later (Kesicioğlu, 2015). By engaging in problem-solving activities, children learn to focus their thoughts, generate alternative solutions, establish cause-and-effect relationships, and predict outcomes (Aydoğan & Ömeroğlu, 2004; Seker, 2017). The key is to provide children with activities specifically designed to foster the development of their problem-solving skills (Karaman et al., 2024). Research suggests that problem-solving skills thrive in environments where curiosity is encouraged, ideas are exchanged, emotions are acknowledged, individual needs are considered, and there is a genuine purpose for learning (Bingham, 2004). Dow and Mayer (2004) also associated the development of problem-solving skills in children with the nature of problems (routine and non-routine). Akçay (2019), on the other hand, stated that cognitive factors (logical thinking, reasoning, etc.), affective factors (motivation, etc.), experience, and demographic variables play a role in this process.

Unplugged coding activities based on electronic materials have the potential to integrate all these components. Some research has reported positive outcomes, which indicates that these activities increase children's problem-solving skills (Canbeldek & Işıkoğlu, 2023; Korkmaz, 2021; Metin, 2022; Nebot et al., 2018). However, other research has noted negative outcomes (Çakır et al., 2021; Çiftçi & Bildiren, 2020). This present research aims to resolve this discrepancy in literature.

3 Method

3.1 Research design

The research was conducted based on a pretest-posttest control group quasi-experimental design, which is one of the quantitative methods (see Fig. 2). The group engaged in unplugged coding activities was designated as the experimental group, while the control group received no experimental intervention and continued with the standard preschool curriculum activities led by the preschool teacher.

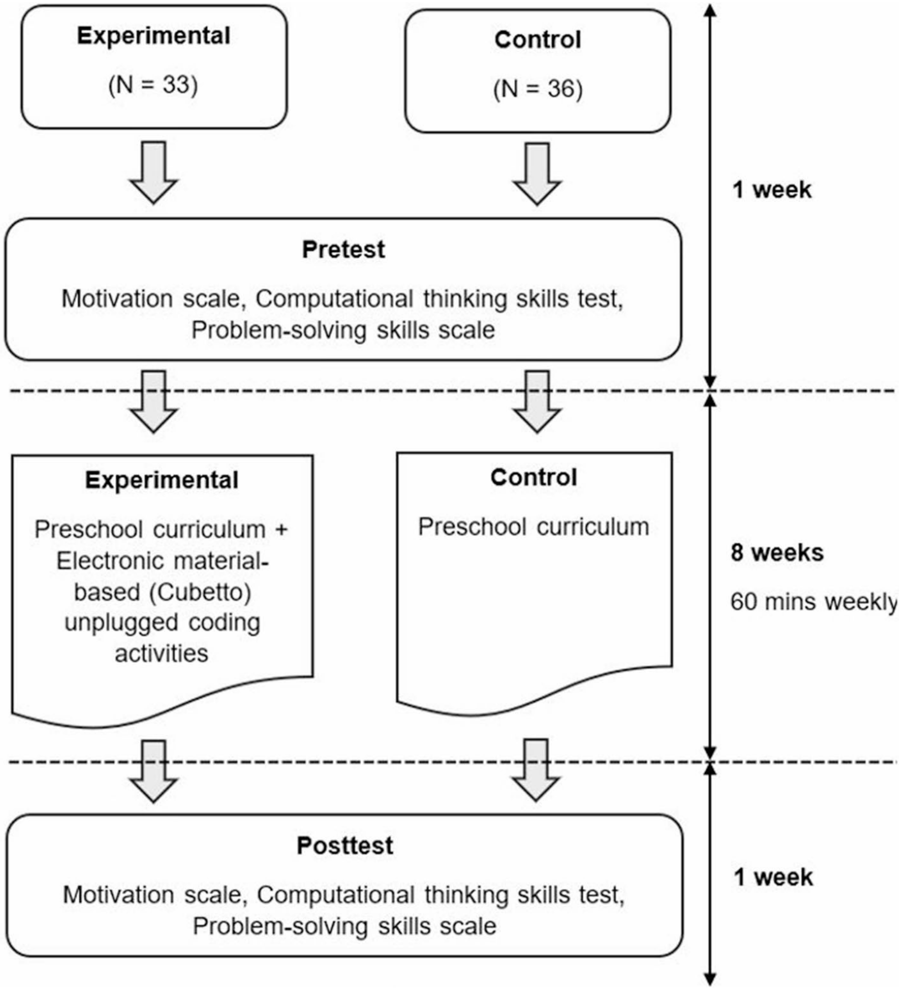


Fig. 2 Research design of this study

3.2 Study group and ethics

This research was carried out during the Fall semester of the 2022–2023 academic year at a public school in Hatay province, Turkey. The school, which operates as a kindergarten, is in a socio-economically moderate area. This school, which has a total of four classrooms, provides half-day education to children in the 5–6 age (60–72 months) category. The four classrooms have equal physical facilities. Each classroom is led by a different preschool teacher, and all teachers follow the same curriculum and deliver similar activities to achieve the same educational outcomes.

The study group comprised 69 children from four classrooms at the school. Two of the classrooms were randomly designated as the experimental group ($N=33$, mean age = 65,5 months), and the other two to the control group ($N=36$, mean age = 65 months). Prior to the research, it was confirmed that the groups were similar in terms of measured variables. Additionally, the distribution of children with prior daycare experience was similar across both groups (6 in the experimental group, 8 in the control group). Neither group included children who had previously received coding education.

The children who expressed a willingness to participate in the Cubetto coding activities were identified by the educators and voluntarily included in the study. However, to respect their autonomy, children were given the right to leave the Cubetto play session and rejoin at any time. Approval was obtained from the University Ethics Committee (approval number E-35853172-300-00001478290), followed by permission for research implementation from the Ministry of Education (approval number E-32889839-605.01-57803623). Parental/guardian consent was then obtained after providing full information about the study. After the study, a debriefing session was held with the teachers to share the findings. Data security was ensured using the 3-2-1 rule, with all data stored in three copies, across two separate media, and preserved in one off-site location.

3.3 Data collection tools

3.3.1 Motivation scale

"The dimensions of mastery questionnaire DMQ18" scale developed by Morgan et al. (1993) was used to determine the motivation level of preschool children. The scale was later revised by Jozsa and Morgan (2015), and an adaptation study was conducted by Özbey and Dağlıoğlu (2017) for the Turkish context. The scale consists of 39 items and 7 sub-scale.

The seven-factor structure of the scale was validated through confirmatory factor analysis, and the alpha reliability coefficients of the dimensions were found to range between 0.84 and 0.91 (Özbey & Dağlıoğlu, 2017). Subsequently, the validity and reliability study of the scale was conducted again by Özbey (2018), and the analysis applied to 401 preschool children once again confirmed the validity of the seven-factor structure. In this analysis, the reliability coefficients of the scale's dimensions ranged between 0.81 and 0.91. The findings indicate that the scale has a high level of reliability (Büyüköztürk et al., 2017).

The motivation scale uses a five-point Likert scale (5: Exactly like him/her, 1: Not at all like him/her). Higher scores reflect greater motivation. The scale is completed separately by the preschool teacher for each child both before and after the intervention.

3.3.2 CT skills test

The CT skills test was developed by researchers with reference to the seven principles defined by Relkin (2018): age appropriateness, authentic interaction, managerial ease, temporal limitation, sensitivity, scoring, and results communication. Initially, 44 questions were created. Based on feedback from experts in Turkish language education (2), computer and instructional technology (6), and preschool education (14), the number of questions was reduced to 20. The test was then administered to 660 children aged 5–6 years from 11 different preschool institutions. Following the analyses, two unsuitable questions were removed. The reliability coefficient of the final test, determined using the KR-20 method, was 0,77, indicating high reliability. The mean difficulty index of the test is 0,47, Suggesting a medium level of difficulty, while the average discrimination index is 0,40, demonstrating good discriminative power.

The final version of the test consists of 18 questions, plus 2 additional questions to help the child become familiar with the test (see Appendix A). These two practice questions are not included in the analysis. The test can measure CT through six components (see Table 1). Each component consists of three questions that progress from easy to difficult. Each correct answer is worth 1 point. The test is available for both printed (paper-based) and online. In this study, it was administered online to groups using the www.bidtesti.com platform, developed by the researchers.

3.3.3 Problem-solving skills scale

The problem-solving skills scale, developed by Oğuz and Akyol (2015) for preschool, features 18 problem situations illustrated with images. Children earn points for their solutions based on the number of suggestions they provide: "0" point for no suggestions, "1" point for one suggestion, "2" points for two suggestions, "3" points for three suggestions, and "4" points for more than three suggestions. The scale's validity was assessed using a content validity index and exploratory factor analysis. The content validity index for item Suitability was 0,99, and for image Suitability was 0,96. The factor analysis revealed a single factor. The reliability coefficient was 0,86, and the test-retest correlation was 0,60, demonstrating the scale's reliability in terms of internal consistency and stability over time.

3.4 Development process of coding material and activities

In this study, Cubetto (see Fig. 1), an electronic-based material, was used to conduct unplugged coding activities with preschool children. The researchers redesigned the material to incorporate these coding activities, following the seven principles identified by Saygıner and Tüzün (2023a) based on expert opinions: developmental appropriateness, authentic interaction, stability, safety and durability, flexibility, intuitive use, and satisfaction. These principles served as a guide for designing materials and activities for teaching coding in the preschool setting. The design and development process followed three steps, which are summarized in Fig. 3.

In the first step, the Cubetto material was adapted to align with the developmental needs of preschool children. During this process, the coding panel was staged to ensure progression from easy to difficult coding, and the coding area was made more prominent. Features indicating direction on the coding blocks were removed, and instead, color was emphasized. Components were added to allow the robot to be operated with one hand. Additionally, features appropriate for each activity were included in the robot. For example, the design of the robot changed from a space vehicle in one activity to an artist painting in another. The robot was also designed to move smoothly on different surfaces.

In the second step, a book that teaches coding through stories was designed (see Appendix B). The book consists of eight different coding adventures of two authentic characters named Defne and Gazella. The coding stories, tasks, or character names in the book were selected from actions or topics that children are familiar with. The tasks in the stories are structured to progress from easy to difficult. There is a strong emphasis on child-child and child-material interaction. The tasks in the coding stories are planned to be carried out collaboratively by the children. In addition, supportive materials for the tasks in the stories (such as a drawing apparatus for the robot, a pen holder, and load-carrying devices) were developed using a 3D printer. Legos, shapes, and concrete figures of the characters were also utilized.

In the third step, six different coding maps were designed for the eight coding activities (see Appendix C). One of these maps was taken ready-made, and another was used in two activities. The maps were designed in accordance with the coding stories.

After the activities were developed, coding sessions were conducted with a group of nine preschool teachers to identify necessary improvements. The experts were selected from individuals with at least 10 years of teaching experience in the 4–6 age group, holding a master's degree, and voluntarily agreeing to participate in the study. These nine experts were randomly divided into two groups. Coding activities were carried out with the five experts in the first group over five days, and after each activity, the *Activity Evaluation Form* prepared by the researchers was administered. The form consists of 18 questions addressing criteria such as "developmental appropriateness, authentic interaction, stability, safety and durability, flexibility, intuitive use, and satisfaction" (see Appendix D). Experts were asked to provide improvement Suggestions for coding activities and rate each question using a scale of 3 (Agree), 2 (Neutral), and 1 (Disagree).

After incorporating the improvements suggested by the five experts in the first group, the same activities were implemented with the four experts in the second group over five days by the same researcher. These experts were asked to complete

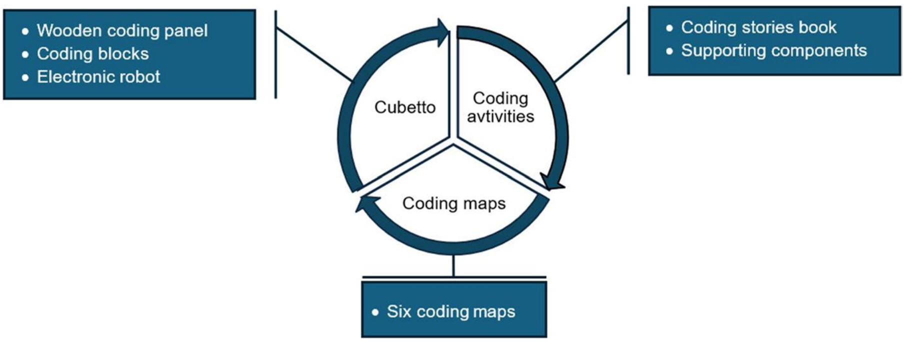


Fig. 3 The design and development process

Fig. 4 Pilot study

the evaluation form after the activities. At the end of this process, the suitability of the developed coding material and activities for the preschool period was validated through expert evaluations. Figure 4 presents an example of an activity conducted with the experts.

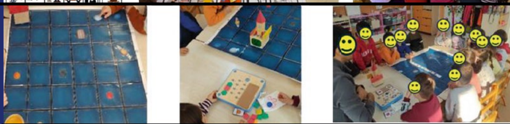
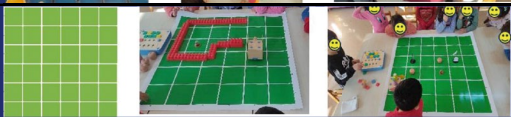
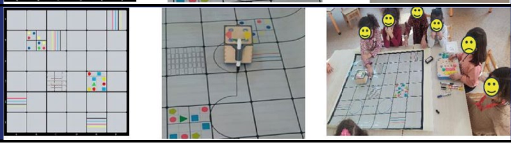
3.5 Experimental process

In the study, electronic material-based unplugged coding activities were conducted with the children in the experimental group over an eight-week period. In this group, coding activities were conducted for eight weeks, with one session per week lasting 60 min. These activities were carried out in the children's own classrooms. The training was conducted by an experienced researcher in coding instruction (Researcher 1). The weekly plan for these activities is detailed in Table 3.

In the control group, activities included in the preschool curriculum continued to be carried out. The curriculum does not include any activities related to coding. In other words, no training or activities related to coding were conducted during the experiment in the control group.

Prior to the research, interviews were held with school administrators and teachers to determine if there were any children with learning difficulties or gifted children in the experimental and control groups. It was also determined whether the children had previously participated in training related to coding, robotics, or cognitive and intelligence games. Additionally, it was confirmed that no other scientific studies were

Table 3 Coding activities performed in the experimental group

Weekly plan	In sequence: Coding map (Picture-1), Cubetto design (Picture-2), and examples of coding activities (Picture-3)
[1st week] "60 minutes" **Material:** Cubetto, animal figures **Coding story:** A day in the wild **Coding map:** Nature map	
[2nd week] "60 minutes" **Material:** Cubetto, colored stones **Coding story:** Escape from the labyrinth **Coding map:** Labyrinth map	
[3rd week] "60 minutes" **Material:** Cubetto, figures, concrete objects **Coding story:** In pursuit of the mysterious treasure **Coding map:** Nature map	
[4th week] "60 minutes" **Material:** Cubetto, profession cards **Coding story:** I am choosing my profession **Coding map:** Profession map	
[5th week] "60 minutes" **Material:** Cubetto, precious stones, planets **Coding story:** Journey to space **Coding map:** Planet map	
[6th week] "60 minutes" **Material:** Cubetto, obstacles, lego walls **Coding story:** Two-stage Survivor track **Coding map:** Survivor map	
[7th week] "60 minutes" **Material:** Cubetto, colorful pencils, drawing apparatus **Coding story:** Wise coder camp: Day-I **Coding map:** Wise-code map	
[8th week] "60 minutes" **Material:** Cubetto, colorful pencils, drawing apparatus **Coding story:** Wise coder camp: Day-II **Coding map:** Wise-code map	

being conducted at the school during the weeks the research was carried out. Considering these explanations, it can be stated that the experimental process of the research was conducted with equivalent groups and under equal conditions.

3.6 Data analysis

For pretest group equivalence, an independent samples *t*-test was used. Changes from pretest to posttest results were examined using a dependent samples *t*-test, while the Wilcoxon Test analyzed changes in CT skills components. Posttest motivation scores were compared using an independent samples *t*-test. ANCOVA analysis was performed to examine the significance of differences between groups regarding CT (the entire test) and problem-solving skills, while controlling for pretest effects.

4 Findings

4.1 Prior checks

To determine whether the groups were equivalent prior to the intervention, the pretest scores for motivation, CT and problem-solving skills were compared. No significant differences were observed between the groups' pretest scores ($p > 0{,}05$ for all tests).

4.2 Findings regarding motivation

The study investigates the effect of unplugged coding activities on children's motivation. After the training, most sub-dimensions of motivation showed a greater increase in the experimental group (see Fig. 5). Significant increases were observed in the dimensions of CP, GMP, SPA, SPC, MP, and GC (see Table 4, $p < 0.05$). However, the increase in the dimension of NR was not significant ($p > 0.05$). Effect size values indicated a low increase in motivation in the NR dimension (Cohen's $d = 0{,}069$), a medium increase in SPA (Cohen's $d = 0{,}463$), and a high increase in all other dimensions (Cohen's d ranging from 0,790 to 1,352).

In the control group, significant increases in motivation scores were found in the dimensions of GMP, SPA, SPC, NR, and GC (see Table 4, $p < 0.05$). Although there was an increase in CP and MP scores in the posttests, this increase was not statistically significant ($p > 0.05$). Effect size values showed a low increase in CP and MP (Cohen's $d = 0{,}320$ and 0,260, respectively), a moderate increase in SPA, SPC, NR, and GC (Cohen's d ranging from 0,398 to 0,598), and a high increase in GMP (Cohen's $d = 0{,}873$). The findings regarding whether this change in posttest scores shows a significant difference between groups are presented in Table 5.

Comparisons of posttest motivation scores revealed that differences favored the experimental group in the dimensions of CP, SPC, MP, and GC (t_{CP}=5,113 $p < 0{,}05$; t_{SPC}=2,369 $p < 0{,}05$; t_{MP}=2,876 $p < 0{,}05$; t_{GC}=4,054 $p < 0{,}05$), while the difference in

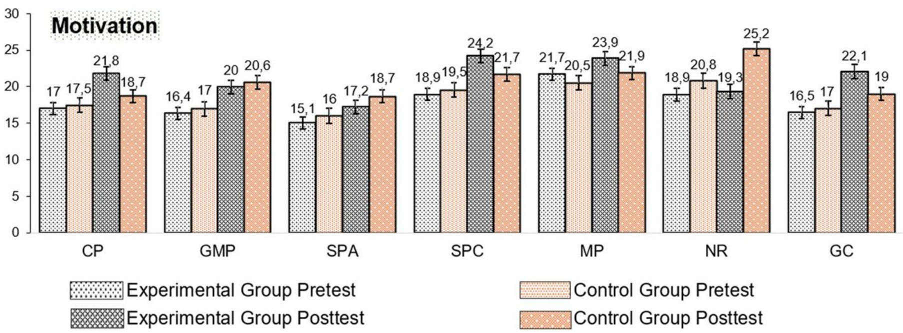


Fig. 5 Change in motivation scores

Table 4 Dependent samples *t*-test results for changes in the groups' motivation scores

		Experimental					Control				
Motivation	Test	$\overline{x}$	df	*t*	*p*	*d**	$\overline{x}$	df	*t*	*p*	*d**
Cognitive persistence	Pretest	17,03	32	6,686	,000*	1,164	17,47	35	1,921	,063	,320
	Posttest	21,82					18,69				
Gross motor persistence	Pretest	16,36	32	4,541	,000*	,790	16,97	35	5,237	,000*	,873
	Posttest	19,97					20,61				
Social persistence with adult	Pretest	15,06	32	2,659	,012*	,463	16,00	35	3,588	,001*	,598
	Posttest	17,24					18,67				
Social persistence with children	Pretest	18,94	32	5,444	,000*	,948	19,53	35	2,531	,016*	,422
	Posttest	24,21					21,69				
Mastery pleasure	Pretest	21,70	32	7,694	,000*	1,339	20,53	35	1,562	,127	,260
	Posttest	23,88					21,86				
Negative reaction	Pretest	18,91	32	,398	,693	,069	20,83	35	2,825	,008*	,471
	Posttest	19,33					25,17				
General competence	Pretest	16,48	32	7,769	,000*	1,352	17,03	35	2,389	,022*	,398
	Posttest	22,09					19,00				

* Cohen's *d*

Table 5 Independent samples *t*-test results for the comparison of the groups' mean motivation posttest scores

Motivation	Group	*N*	$\overline{x}$	SS	df	t	*p*	Cohen's d
Cognitive persistence	Experimental	33	21,82	1,991	67	5,113	,000*	1,232
	Control	36	18,69	2,945				
Gross motor persistence	Experimental	33	19,97	2,756	67	-,843	,402	,203
	Control	36	20,61	3,483				
Social persistence with adult	Experimental	33	17,24	3,800	67	−1,555	,125	,375
	Control	36	18,67	3,802				
Social persistence with children	Experimental	33	24,21	4,526	67	2,369	,021*	,571
	Control	36	21,69	4,302				
Mastery pleasure	Experimental	33	23,88	1,293	67	2,876	,005*	,693
	Control	36	21,86	3,833				
Negative reaction	Experimental	33	19,33	4,903	67	−4,432	,000*	1,068
	Control	36	25,17	5,926				
General competence	Experimental	33	22,09	2,614	67	4,054	,000*	,977
	Control	36	19,00	3,594				

the dimension of NR favored the control group (t_{NR}=−4,432 $p<0,05$). According to effect size values, the differences were moderate in SPC (Cohen's d_{SPC}=0,571) and relatively high in CP, MP, NR, and GC (Cohen's *d* ranging from 0,693 to 1,232). No significant differences were found between the groups in the dimensions of GMP and SPA (t_{GMP}=−0,843 $p>0,05$; t_{SPA}=−1,555 $p>0,05$).

4.3 Findings regarding computational thinking skills

This study also seeks to determine the effects of unplugged coding activities on children's CT skills. The initial analysis was conducted based on the components of CT.

In the experimental group, a high and significant increase was observed in all components after the training, while the control group experienced a low and insignificant increase in scores (see Fig. 6; Table 6).

An evaluation was also conducted based on the entire test to reveal the change in CT skills from the pretest to the posttest within the groups. The total test score distribution of the groups in Fig. 7 showed a significant increase in the experimental group, while a low-level increase was observed in the control group. It was observed that the CT skills of the children in the experimental group progressed from a low (novice) level to a high (expert) level, whereas in the control group, the skills remained at

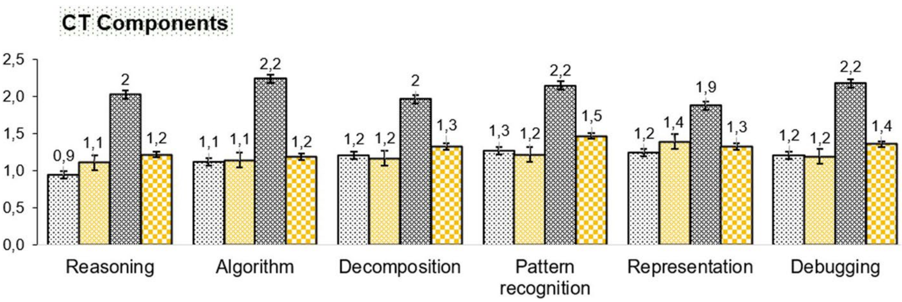


Fig. 6 Change in CT component scores

Table 6 Wilcoxon test results for changes in the groups' CT components scores

CT components	Posttest-Pretest	Experimental					Control				
		N	Rank $\overline{x}$	Rank $\sum$	Z	*p*	N	Rank $\overline{x}$	Rank $\sum$	Z	*p*
Reasoning	Negative	23	14,41	331,50	−4,057	,000	11	9,82	108,00	-,556	,578
	Positive	3	6,50	19,50			8	10,25	82,00		
	Equal	7					17				
Algorithm	Negative	21	12,71	267,00	−4,011	,000	10	9,30	93,00	-,346	,729
	Positive	2	4,50	9,00			8	9,75	78,00		
	Equal	10					18				
Decomposition	Negative	17	11,12	189,00	−3,245	,001	14	15,54	217,50	-,705	,481
	Positive	3	7,00	21,00			13	12,35	160,50		
	Equal	13					9				
Pattern recognition	Negative	24	14,44	346,50	−3,985	,000	16	15,22	243,50	−1,391	,164
	Positive	3	10,50	31,50			11	12,23	134,50		
	Equal	6					9				
Representation	Negative	20	13,95	279,00	−2,761	,006	12	12,33	148,00	-,407	,684
	Positive	6	12,00	72,00			13	13,62	177,00		
	Equal	7					11				
Debugging	Negative	23	12,72	292,50	−4,207	,000	14	13,96	195,50	-,932	,351
	Positive	1	7,50	7,50			11	11,77	129,50		
	Equal	9					11				

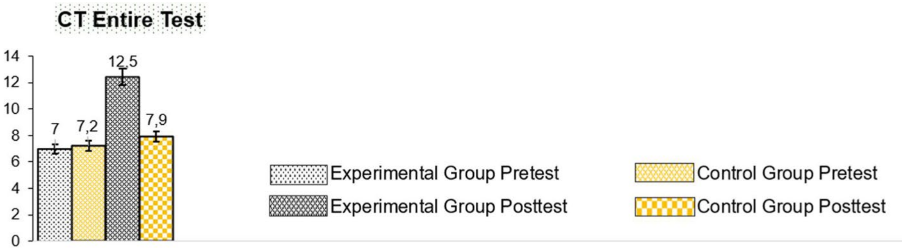


Fig. 7 Change in CT entire test scores

Table 7 Dependent samples *t*-test results for changes in the groups' CT and problem-solving scores

		Experimental					Control				
		$\overline{x}$	df	*t*	*p*	*d**	$\overline{x}$	df	*t*	*p*	*d**
CT [The entire test]	Pretest	7,000	32	12,168	,000*	2,118	7,222	35	1,882	,068	0,314
	Posttest	12,455					7,917				
Problem-solving	Pretest	29,970	32	7,854	,000*	1,367	26,833	35	5,730	,000*	0,955
	Posttest	46,333					33,139				

* Cohen's *d*

Table 8 The ANCOVA analysis on the posttest scores for CT and problem-solving between the groups

Variable	Source of variance	Sum of squares	df	Mean of squares	F	*p*	η^2
CT [The entire test]	Pretest	74,612	1	74,612	15,869	,000	,194
	Group	371,123	1	371,123	78,932	,000*	,545
	Error	310,320	66	4,702			
	Adjusted total	739,478	68				
Problem-solving skills	Pretest	1873,257	1	1873,257	21,590	,000	,246
	Group	2010,227	1	2010,227	23,169	,000*	,260
	Error	5726,382	66	86,763			
	Adjusted total	10597,072	68				

the low (novice) level. Findings regarding the significance of these evaluations are presented in Table 7.

According to Table 7, the increase in the scores of the experimental group after the implementation was statistically significant (t_{32}=12,168, p<0,05). The increase in the posttest scores of the control group, on the other hand, was not found to be statistically significant (t_{32}=1,882, p>0,05). The effect size indicated a high-level increase in the experimental group (Cohen's d=2,118) and a low-level increase in the control group (Cohen's d=0,314).

Whether the change observed in the total posttest scores constituted a significant difference between the groups was examined using ANCOVA analysis (see Table 8). According to the results of the analysis, the difference observed between the experimental and control groups was statistically significant in favor of the experimental group ($F_{1\text{-}66}$=78,932, p<0,05). According to the effect size value, the difference was at a high-level (η^2=0,545).

4.4 Findings regarding problem-solving skills

Another aspect of the research examined the effect of unplugged coding activities conducted in the preschool period on children's problem-solving skills was examined. Problem-solving skill scores increased in both groups (see Fig. 8). This increase was much higher in the experimental group compared to the control group. Findings regarding whether this increase observed in the posttest scores of the groups was significant are presented in Table 7.

According to Table 7, the increase in scores observed in the experimental and control groups after the intervention was statistically significant (Experimental $t_{32}=7{,}854$, $p<0{,}05$, Control $t_{35}=5{,}730$, $p<0{,}05$). Based on the effect size values, the increase in scores observed in the experimental (Cohen's $d=1{,}367$) and control (Cohen's $d=0{,}955$) groups was at a high-level.

A comparative analysis of the posttest scores of the groups was conducted using ANCOVA (see Table 8). According to the analysis results, there was a statistically significant difference between the groups in favor of the experimental group ($F_{1\text{-}66}=23{,}169$, $p<0{,}05$). The effect size value indicated that this difference between the groups was at a high-level ($\eta^2=0{,}260$).

5 Discussion

This study investigated the effects of electronic material-based unplugged coding activities conducted with preschool children on their motivation, CT and problem-solving skills. The research provides empirical evidence of the impact of coding activities on these three variables. The results, which show the group differences, are presented in Table 9, followed by a detailed explanation of these findings.

5.1 Motivation

The research primarily focuses on motivation. After the activities, the experimental group showed greater increases in intrinsic motivation dimensions: CP, SPC, MP, and GC. CP reflects the effort children put into completing tasks, SPC denotes their determination to interact with peers, MP is the satisfaction from achieving tasks, and GC indicates problem-solving skill acquisition (Özbey & Dağlıoğlu, 2017). Significant

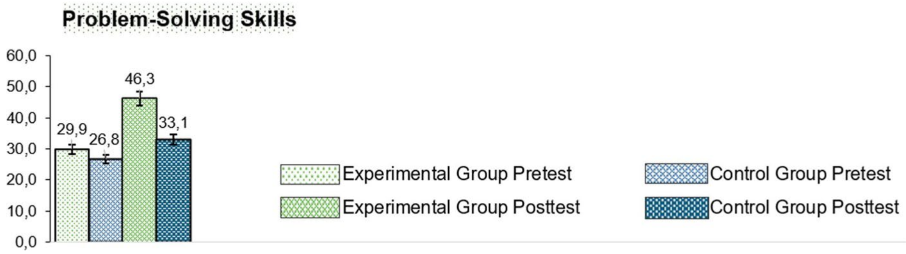


Fig. 8 Change in problem-solving scores

Table 9 Summary of the results

Data collection tools	Experimental (Preschool curriculum + Unplugged coding activities)	*	Control (Preschool curriculum)
Motivation scale	Cognitive persistence	>	Cognitive persistence
	Gross motor persistence	≈	Gross motor persistence
	Social persistence with adult	≈	Social persistence with adult
	Social persistence with children	>	Social persistence with children
	Mastery pleasure	>	Mastery pleasure
	Negative reaction	<	Negative reaction
	General competence	>	General competence
CT skills test	Reasoning	>	Reasoning
	Algorithm	>	Algorithm
	Decomposition	>	Decomposition
	Pattern recognition	>	Pattern recognition
	Representation	>	Representation
	Debugging	>	Debugging
	CT [the entire test]	>	CT [the entire test]
Problem-solving skills scale	Problem-solving skills	>	Problem-solving skills

* ">" Differences in favor of the experimental group; "≈" similar level of change; "<" Differences in favor of the control group

differences favoring the experimental group were observed in these four motivational dimensions.

The coding activities in the experimental group were game-based and problem-solving oriented, involving cognitive tasks such as exploration and problem-solving, as along with social interactions like collaboration and communication. These activities likely motivated children to engage in problem-solving. A study by Tüzün (2004) examined the motivations of children playing educational games in a computer environment. The study found that seeing other children playing games or hear conversations about the games created a ripple effect for their own involvement in the game. This phenomenon, referred to as the "peer effect" in the study, was considered the stage where curiosity was triggered (Tüzün, 2004). It is believed that conducting coding activities together in a real environment, like the virtual environment, may have enhanced the children's sense of engagement in the process. At this point, the scope of the coding activities should also be mentioned. Authentic stories and supportive concrete components were integrated into the activities, which may encourage children to take action in solving problems. Many researchers have also emphasized that these qualities contribute to developing coding experiences for preschool children (Lee & Cho, 2017; Metin, 2022; Pugnali et al., 2017; Sullivan & Bers, 2016).

During the experiment, certain activities designed to actively maintain the children's curiosity For example, varying maps were developed for the coding activities, and the design of the coding materials was adopted to align with the storyline for each activity. Additionally, the idea that Defne and Gazella would undertake different tasks in each activity and that children needed to help them likely helped sustain the children's curiosity. The task of assisting the characters may have encouraged children to develop empathy and form a stronger bond with the characters. This, in turn, may have fostered a sense of being part of the story. Consequently, children may have shown more participation and persistence in the activities with a desire to fulfill their given responsibilities. Increased participation may have enabled them to master more complex problems. Furthermore, successfully completing each task may have given children a sense of pride in helping Defne and Gazella. These factors likely contributed to the experimental group's enhanced cognitive persistence, increased peer interaction, higher satisfaction, and improved problem-solving skills.

Another critical outcome of the research is that the control group showed a high rate of increase in the NR dimension, while the experimental group exhibited only a small and non-significant increase. This dimension encompasses emotions such as shame, disappointment, anger, or sadness that children feel when they are unable to accomplish a task (Özbey & Dağlıoğlu, 2017). This difference may be attributed to the varying perceptions of making mistakes and the influence of empathy in the coding activities.

Making mistakes is a crucial component of the coding instruction process. During coding activities, children are encouraged to understand that making mistakes is a normal part of the learning process and to learn how to address and respond to these mistakes. Additionally, even if children do not make mistakes in coding, it is a common strategy to deliberately produce faulty codes and ask children to come up with solutions to these mistakes. This can be seen as an intervention that helps children become better problem-solvers. Because when a mistake is corrected, the child can start to have a positive feeling about their own skills.

In all the coding activities with the experimental group, debugging was frequent component. Children were encouraged to resolve mistakes through problem-solving rather than expressing negative reactions. This approach likely led them to focus on finding solutions rather than reacting negatively to failure. Additionally, the positive contributions of children working together during the error detection process may have also played a role. According to a study by Tüzün (2004), receiving help from peers did not create a sense of embarrassment in children; in fact, children who received help were very satisfied with the situation. The study suggests that knowing there is always someone available to help in the environment encourages persistence in tasks (Tüzün, 2004).

Another factor that may have reduced NR in the experimental group is empathy. Çankaya (2014) found that higher empathy levels in children were associated with fewer undesirable reactions. Kabapınar et al. (2019) reported that story-based activities enhance children's empathy skills. Therefore, it can be concluded that the story-based and interaction-focused activities in the experimental group likely increased children's empathy, which in turn reduced their NR.

Another result regarding motivation is that increases were observed in both the GMP and SPA dimensions for both the experimental and control groups, but no significant difference was found between the groups. GMP refers to children's endurance in physical activities, while SPA indicates the children's determination to attract the attention of adults (Özbey & Dağlıoğlu, 2017).

Among unplugged coding categories (see Table 1), it can be said that, except for kinesthetic movement-based coding activities, other types involve fewer actions that develop GMP. In other words, the lower experience of physical movements that enhance GMP during the coding activities conducted with the experimental group may have contributed to this result. The studies indicates that electronic material-based coding activities are more closely associated with fine motor skills in children (Bozkurt-Polat & Ulutaş, 2023).

The SPA dimension is more related to extrinsic motivation, as children in this dimension try to continue activities to attract adult attention. The research findings suggest that children in the experimental group were more intrinsically motivated. This is evidenced by the significant difference in the CP dimension favoring the experimental group. In other words, the children continued with the coding activities out of a desire to succeed, rather than to gain adult attention.

5.2 Computational thinking skills

Another focus of the research was on CT skills, assessed through components. After the activities, the experimental group showed significant increases in all six components, while the control group showed no significant change. The largest increases in the experimental group were in algorithm and logical reasoning, and the smallest was in representation. These differences likely stem from the structure of the coding activities.

Coding is fundamentally a problem-solving process (Saygıner & Tüzün, 2018). It starts with a logical evaluation of the problem and evolves into creating appropriate solution scenarios (Pea & Kurland, 1987). Reasoning and algorithm are closely related to these steps. Encountering more problems can enhance the ability to establish logical relationships and gain experience in algorithm production. The experimental group focused on these two components, engaging in activities centered on creating algorithms and reasoning across all eight sessions. In contrast, content related to the representation component was mainly limited to six activities. Coding activities were designed to progress from easy to difficult, considering children's developmental characteristics. Therefore, activities involving all six CT components became more intensive after a few lessons. Consequently, the varying development rates of these components can be seen as a normal process.

The research also noted a significant improvement in debugging skills within the experimental group. This increase may be attributed to the visual presentation (with blinking lights) of each coding step in the Cubetto material. This feature allowed children to progress their code step by step and visually track which code was active at that moment. Relevant literature emphasizes that the step-by-step progression feature of the material helps children solve problems at their own pace (Misirli & Komis, 2023; Sipitakiat & Nusen, 2012; Tezcan, 2025).

The research showed that the total scores from the CT test were significantly higher in the experimental group which indicates that unplugged coding activities utilizing the Cubetto material effectively developed children's CT skills. The activities' suitability for children's interests, along with their exciting and fun nature, likely encouraged active participation. Stocklmayr et al. (2011) noted that such activities motivate and increase children's willingness to participate. Similarly, Relkin et al.

(2021) found that their CT skills also develop as children's participation levels in activities increase.

The idea that the children in the experimental group actively participated in the activities is also confirmed by the scores obtained from the CP and MP dimensions, which are indicators of motivation. This indicates that applying specific principles (Saygıner & Tüzün, 2023a) in the design of coding materials and activities has the potential to enhance children's interest and participation levels.

The research indicates that CT skills improve when coding materials and activities are designed to align with the developmental characteristics of children. In this context, the results of this study differ from those of previous research that provides a more general evaluation of CT skills (Clarke-Midura et al., 2023; Critten et al., 2022; Marinus et al., 2018; Polat, 2023; Saxena et al., 2020).

5.3 Problem-solving skills

This study also examined the effect of unplugged coding activities on children's problem-solving skills. The results showed a significant improvement in both groups compared to pretest scores. However, the experimental group demonstrated a more significant improvement in problem-solving skills compared to the control group. Analyzing the posttest scores also showed a notable difference in favor of the experimental group.

The literature presents contradictory results compared to the findings of this study. For example, Çiftçi and Bildiren (2020) conducted screen-based coding activities via the code.org platform with children aged 4–6 for 8 weeks. They reported no significant change in the children's problem-solving skills after these activities (Çiftçi & Bildiren, 2020). The differences between the findings of this study and those in the relevant literature may be attributed to the manipulative, concrete, intriguing, and collaborative characteristics of unplugged coding activities.

The manipulative features of the Cubetto material used in the experimental group allowed children to try different combinations, observe the results, and make their own discoveries. Additionally, the fact that in each activity, the children found themselves in a different coding story and helped the characters in the story with their tasks may have increased their curiosity and participation levels. Furthermore, experiencing coding in a collaborative environment may have contributed to the development of their observational problem-solving skills.

Research has highlighted that trial-and-error approaches (Thorndike, 1913) and observing others' behaviors (Bandura, 1986) are effective methods for enhancing problem-solving skills. Bingham (2004) also associated the development of this skill with activities where curiosity is encouraged, opinions are discussed, emotions are considered, individual needs are considered, and there is a real purpose for learning.

Dow and Mayer (2004) linked the development of problem-solving skills to the nature of problems (routine vs. non-routine). In routine problems, children generally know the solution method, whereas in non-routine problems, they must develop the solution through a cognitive process. This study emphasized non-routine problems in the experimental group. The coding activities were story-based, included supportive components to concretize the stories, and featured robot decorations that aligned with the narrative. These features likely contributed positively to developing problem-solving skills in children. As stated by Dow and Mayer (2004), the non-routine nature of the coding activities may have stimulated a more intense mental process in the experimental group. As a natural consequence of this process, the problem-solving skill was likely more developed.

The differences in problem-solving skills between the groups may also have been influenced by the children's motivations. Research indicates that the development of problem-solving skills is particularly dependent on intrinsic motivation (Güss et al., 2017; Köyceğiz & Özbey, 2019; Pintrich, 2000; Urhahne, 2021; Yurtseven & Doğan, 2019). Children who are intrinsically motivated often show a stronger interest and enthusiasm for solving problems, dedicating more time and effort. Consequently, motivated children are more likely to engage in problem-solving processes.

5.4 Limitations

Unplugged coding activities are categorized into four types (see Table 11), each offering distinct features. This research focused on electronic-based coding activities, so the results are applicable to this sub-category of unplugged coding. Motivation is typically assessed using self-report methods, which can be challenging for preschool children due to their developing language skills. Hence, in this study, preschool teachers completed the motivation scale for each child, which makes the motivation assessments dependent on the teachers' evaluations.

6 Conclusion and recommendations

The study provides empirical evidence on the scope and effectiveness of electronic material-based unplugged coding activities in preschool education. This data lays a strong foundation for the widespread adoption of coding education at the preschool level. It is recommended that future research focuses on developing unplugged coding curricula and programs tailored for preschool settings. In parallel, it is recommended that professional development programs be designed to equip preschool teachers with the knowledge and skills necessary to effectively implement these activities in the classroom.

This study yielded notable results regarding children's motivation. Of particular significance is the finding that unplugged coding activities enhanced dimensions related to intrinsic motivation while preventing NR in the event of failure. The potential of these activities to reduce NR in children could stimulate theoretical discussions in literature. More comprehensive research on this topic could further deepen the relevant conceptual perspective.

Additionally, this study provides compelling evidence that unplugged coding activities significantly contribute to the development of children's CT and problem-solving skills. It highlights that coding activities should be adapted to children's developmental levels, include elements of discovery and curiosity, foster collaboration, involve authentic tasks and trigger a sense of empathy. It is recommended that these factors should be carefully considered when designing and conducting coding activities in preschool settings.

On the other hand, implementing such activities in resource-limited schools may pose several practical challenges. Factors such as teachers' lack of knowledge about coding, insufficient coding materials, overcrowded classrooms, and limited instructional time can negatively affect the implementation process. In this context, it is recommended that future experimental studies explore the integration of elements found to be effective in this study, such as exploration, curiosity, collaboration, authentic tasks and empathy, into other coding approaches (see Table 1). This would not only enhance the diversity of implementation strategies but also contribute to sustainable solutions for addressing resource limitations.

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Data availability In order to protect the privacy of the participants, the data are not presented openly. However, the data supporting the findings of this study can be made available upon reasonable request.

Declarations

Competing interest The authors declare that there are no conflicts of interest associated with this publication. This manuscript is the original work of authors, and all authors mutually agree for its submission.

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