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Exploring the effects of "productive children: coding and robotics education program" in early childhood education

Merve Canbeldek[1] · **Nesrin Isikoglu**[1]

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Abstract
Recently, coding and robotics education has started to be integrated into early childhood education in Turkey. The current study aims to investigate the effects of "Productive Children: Coding and Robotics Education Program (PCP)" on children's cognitive development skills, language development and creativity. Eighty children, enrolled in four different public kindergarten classrooms, participated in the study. Four classrooms were randomly assigned to two experimental and two control groups. The PCP was implemented in the experimental group at least twice a week for nine weeks. This program consists of three parts: unplugged coding, robotic tools and block coding. Before and after this intervention, all children's cognitive, language and creative skills were measured. The results revealed that PCP, which is integrated into early childhood education activities, positively affects the cognitive development skills, language development and creativity of children. Additionally, there were statistically significant differences between the post-test scores of groups in favor of the experimental groups.

Keywords Early childhood education · STEM education · Computational thinking · Coding and robotic education · Technology

✉ Merve Canbeldek
mcanbeldek@pau.edu.tr

Nesrin Isikoglu
nisikoglu@pau.edu.tr

1 Early Childhood Education Department, Pamukkale University, Denizli, Turkey

1 Introduction

Teaching children twenty-first century skills including critical thinking, problem solving, cooperation, communication, creativity, and innovation has been considered valuable for children's future success in this digital world. Such curriculum well known as Science, Technology, Engineering, Mathematics and Arts (STEM or STEMA) has begun to attract the attention of early childhood teachers and families (Akgündüz & Akpınar, 2018; Metin, 2020; Siper-Kabadayı, 2019; Turan & Aydoğdu, 2020). In the technology part of STEM activities, coding and robotics are seen as new literacy that is an essential tool for reading, interpreting data, and communicating with others in a digital society (Bers, 2019). Generally, coding (programming) is defined as a basic language containing the process of creating step-by-step instructions for a computer, a machine, or a person to understand or move (McLennan, 2017).

Recently, coding has become an increasingly growing focus in early childhood education in various countries including the United States, England, Estonia, Singapore, and Australia (Bers, 2018; NAEYC & Fred Rogers Center for Early Learning and Children's Media, 2012; Newsroom, 2018; Patel, 2019; Robogarden, 2020). Well-known organizations such as NAEYC and Fred Rogers Center for Early Learning and Children's Media (2012) have prepared guides and examples to teach developmentally appropriate coding and technology literacy skills to young children, and they suggested that these trainings should be integrated into the early childhood education curriculum and involved in play-based learning (NAEYC, 2022). Moreover, global campaigns such as "Everyone Should Learn to Code" and "code.org"have started to draw public attention to teaching coding skills. Furthermore, some countries such as Estonia, Singapore, and England have prepared regulations and teacher trainings to teach coding skills to young children (Newsroom, 2018; Patel, 2019; Robogarden, 2020).

Similarly, the Turkish Ministry of National Education (MoNE) has started several initiatives such as offering coding education to both children and teachers through the Education Information Network (EBA), and campaigns, completions, and projects such as "Think, Design, Code", "Computer Programming is a Piece of Cake", "Code Your Dreams", "Come on Girls to Coding" or "Little Hands Are Coding." (Akyol-Altun, 2018; Bender, 2018; Gökbulut, 2019; Kalelioğlu, 2015; MoNE, 2017). In the context of Turkey, and other countries, teaching coding skills to children and teachers has become increasingly important, as such training produces individuals who are technologically competent and align to other skills believed to be essential for success in the twenty-first century.

Recent study findings on the effects of coding and robotics education programs show promising results for young children (Bers et al., 2019; Chun & Park, 2020; Saxena et al., 2020; Strawhacker & Bers, 2019). Most of the important work about the effects of coding activities examines children's computational thinking skills. These studies confirm that coding and robotics education supports young children's computational thinking skills (Angeli & Valanides, 2020; Kalogiannakis & Papadakis, 2017; Kazakoff et al., 2013; Papadakis et al., 2016; Roussou & Rangoussi, 2020; Saxena et al., 2020). Gaining computational thinking skills can induce changes in the way people think (Papert, 1980; Resnick, 1996). These skills are considered fundamental skills for reading, writing, and arithmetic which should be accordingly taught at an earlier age (Barr et al., 2011; Sullivan & Bers, 2015).

Research on coding and robotics education has also investigated the possible effects on the children's other developmental areas. For example, Chun and Park (2020) found that a cohort of 5-year-old children showed increased developmental levels for creative and social personalities after only five weeks of participating in unplugged coding activities. Other results indicate that teaching computational thinking skills—fundamental practices for coding and robotics—supports sequencing skills in children (Caballero-Gonzalez et al., 2019; Kazakoff & Bers, 2014; Saxena et al., 2020). Similarly, research findings showed that participating coding and robotics activities enhanced children's problem-solving skills (Akyol-Altun, 2018; Koç, 2019), visual-spatial skills, working memory, and inhibitory control skills (Di Lieto et al., 2017). In early childhood education, these findings give promising results, however, research to explore the effects of coding education in various areas of development remains limited and mostly depends on qualitative research.

1.1 Theoretical basis of coding and robotics activities in early childhood education

Since the development of the Logo programming language, the idea of teaching young children coding and robotics has become a reality (Feurzeig & Papert, 2011; Papert, 1980; Resnick, 2019). Papert (1980) argued that with a robot called "Logo Turtle" children improve thinking and problem-solving skills in a play environment. Currently, with the development of new computer interfaces and block coding programs, even the three-year-old children can learn coding (Bers, 2018; Elkin et al., 2016; Papadakis et al., 2016; Strawhacker et al., 2018). A recent study's results have shown that three-years-old children build and program simple coding activities (Bers et al., 2019). Similar research suggests that it is also crucial to provide hands-on and child-centered coding and robotics activities for meaningful learning at this age (Bers & Horn, 2010; Geist, 2016; Horn et al., 2011; Metin, 2020; Strawhacker & Bers, 2019; Sullivan & Bers, 2015). Young children in this age group learn through play and exploration in a safe and stimulating environment by interacting, communicating, thinking, and problem-solving (Piaget, 1953). Drawing upon Piaget's and Papert's ideas of constructionist learning, meaningful learning occurs when the learner experiences as constructing a meaningful product (Harel & Papert, 1991). According to Papert (1980), constructionist method allows students to learn about a subject by exposing them to multiple problems and asking them to construct their understanding of the subject through these problems. These ideas provide a strong theoretical base for Productive children: coding and robotics education program.

On the other hand, there are still unresolved issues and challenges regarding how to provide concrete, meaningful and problem-based learning activities to teach coding to young children (Dorouka et al., 2020). Recently, Bers (2020) employs the concept of "coding as a playground," pointing to the importance of coding activities that are developmentally appropriate as well as emphasizing the importance of opportunities for children to play, explore, socialize, and be creative during the coding and robotics education (Bers, 2020; Lee, 2019). Mainly such activities range from unplugged and block coding to robotics education (Bers et al., 2019; Metin, 2020). For young children there are two types of coding activities named as unplugged (coding without computer, tablet, or any screen) and plugged-in (Lee & Junoh, 2019). Several studies suggest that it is important to start with unplugged coding which allows children to physically move things around without requiring abstract coding (Campbell & Walsh, 2017; Chun & Park, 2020; Lee & Junoh, 2019; Metin, 2020). In a recent study, Saxena et al. (2020) revealed that young children can learn target skills (pattern recognition, sequencing, and algorithm design) through unplugged and plugged activities. Moreover, tangible technologies which allow the interaction and manipulation of digital information through physical objects (González-González et al., 2019) including robots or other electronic toys have become a part of developmentally appropriate coding activities (Bers & Horn, 2010; Chan, 2020).

It is also important to note that coding and robotics education is a new concept for early childhood teachers and has not been comprehensively integrated into most early childhood curricula. Again, early education teachers' lack of knowledge about robotics and coding, their negative attitudes towards technology, and financial constraints to buy necessary digital tools remain a huge obstacle for integration of coding and robotics education in early education (Park, 2011; Wajszczyk, 2014). For these reasons, Turkish families believing in the value of coding and robotics education for their young children send their children to private lessons and after-school programs and pay high fees for learning coding and robotics (Sayın, 2020). This trend has two potential problems; (1) in private lessons or after-school programs children learn mere coding skills without making connections to their other learning areas i.e., language, science, or math, (2) creating inequities for children from socio-economically disadvantaged families. These issues related to universal access to coding and robotics education indicate the need for more research in support of national education program goals to provide equitable access for all children to experience twenty-first century STEM learning environments. Therefore, this study aims to propose and measure the effects of a program called "Productive Children: Coding and Robotics Education Program (PCP)".

This quasi-experimental study aims to overcome the issues about coding and robotics education by (1) designing PCP for early childhood education, (2) integrating PCP activities to daily curriculum (3) examining the effects of PCP on children's different developmental domains such as language, cognition, and creativity. The PCP is unique in terms of combining unplugged coding, robotic tools, and block coding activities that can be integrated into traditional early childhood activities, (e.g., play, art, music, math, science, and reading), and delivered through child-centered pedagogical approaches.

2 Method

2.1 Research design

The current study employs a pretest-posttest control group quasi-experimental design to analyze the effectiveness of the PCP (Ary et al., 2014; Creswell, 2012;

Shadish et al., 2002). The dependent variables of the study are the scores obtained from the children's cognitive development, language development, and creativity skills questionnaires, while the independent variable is the PCP implemented in the experimental group.

2.2 Participants

Participants were recruited from a public kindergarten in Denizli which is a medium-sized city in western Turkey with about 700.000 inhabitants. The participating kindergarten was chosen randomly among 21 kindergartens in this area. Approximately 300 children were attending at the school and children were placed into classrooms according to their age. Four classrooms housing 5-year-old children were randomly assigned to two experimental and two control groups. Following institutional review board permission, the invitation letter and informed consent forms were sent to the parents. The purpose and procedures of the study were explained to both parents and teachers, then they were asked to fill in a consent form to participate. Pamukkale University's Ethical Guidelines (2019) were followed at all the stages of the study.

The initial sample consisted of 90 children aged 60–72 months-old; but four were dropped for inclusion, six were dropped for lower attendance to the classrooms. The final sample comprised 80 children (39 in experimental groups, 41 in control groups). The mean age between groups (69.67 months in experimental; 68.34 months in control groups) was not significantly different ($p = .807$). Parents reported their highest education completed as: college (56.4%) in experimental and (48.8%) in control groups.

2.3 The development of the productive children coding and robotics education program (PCP)

Through the lens of constructionist learning, PCP focused on engaging children in playful and problem-solving activities as constructing hands-on products. PCP is composed of three basic activities including unplugged coding, robotics, and block coding that is designed around concrete-to-abstract principles (Walsh & Campbell, 2018). PCP activities include five basic coding concepts including algorithm, sequencing, branching, loops, and decomposition, and these concepts were delivered through play-based and hands-on activities. All PCP activities are integrated into traditional small or large group early childhood activities such as math, science, language, arts, music and play. An overarching theme, "environmental awareness," was used to provide additional context for all coding activities.

The PCP program has a total of twelve unplugged coding activities which consist of screen-free, concrete play-based activities that uses grid-based coding games to teach children about sequencing, algorithms and debugging (See Fig. 1). For these activities, organized as two activities per day over three weeks, an 8×8 coding grid was drawn on the floor of the two classrooms. A doll named Ece was placed into the classrooms and children were instructed to help the doll Ece to protect the environment. Frequently, unplugged coding activities started with reading a picture book to lay a contextual foundation for problem-solving.

Following unplugged coding activities, PCP contained eleven screen-free coding activities using robotics. For these activities, three different robotic tools (Matatalab, Bee-Bot, and Doc) were employed using learning mats placed in the classrooms. The children were asked to use these robots, individually or in small groups, to code certain tasks they planned. Individual and small group activities enabled the children to actively participate in the coding process and master coding commands. While a small group of the children took turns working with the robots, the others played in the learning centers. (See Fig. 2).

The last part of the PCP contained six block coding activities in which the children used the "Scratch Jr" application that allowed the children to record their own voices and create their own stories. For this part of the PCP, five tablet computers were provided and the children used them in pairs. Each Scratch Jr. activity was saved by the children and later they were able to continue where they left off. (See Fig. 3).

To ensure the content validity, PCP activities were sent to five curricular experts to evaluate the appropriateness of the activities to reach program goals. Based on their feedback, the PCP was rearranged, and a final version of PCP was organized.

2.4 Procedure

Children voluntarily participated in PCP activities. Before implementation, pre-tests were conducted with both experimental and control groups. Based on the testing procedures, children were tested as a group or individually in a quiet room. PCP activities were conducted twice a week for nine weeks in classrooms designated as experimental groups. These activities occurred on Monday and Wednesday in one experimental group and on Tuesday and Thursday in the other. PCP activities were conducted during free play times in small groups, and some were conducted during the circle times as large group activities. The activities lasted approximately for

Fig. 1 A sample of unplugged coding activity

Fig. 2 A sample of with robotics tools coding activity (Bee-Bot)

30–60 minutes. At the end of nine weeks, the post-tests were administrated to the children in both experimental and control groups.

2.5 Data collection tools

2.5.1 Test of early language development (TELD-3)

Children’s expressive and receptive language development was measured by the “Test of Early Language Development Third Edition (TELD-3)” developed by Hresko, Reid, and Hammill (1999) and translated into Turkish by Topbaş and Güven (2011). TELD-3 is a standardized test that measures language skills of children between the ages of two and seven. The test uses a picture book, objects (e.g., coins, toys, etc.) and verbal commands (e.g., “Point to your nose”). For each item, the child is given a verbal direction and then shown a stimulus object or a picture. The child is then asked to respond to prompts for each item and their response is scored.

The TELD-3 has two parallel forms, A and B and each form has 37 items to assess receptive language and 39 items to assess expressive language. A test-retest method was used to determine the reliability of TELD-3 and correlation coefficients were .96 for the receptive and .89 for the expressive language (Güven & Topbaş,

Fig. 3 A sample of block coding activity

2014). In the current study, the reliability coefficient was calculated as .86. Additionally, ensuring reliability among the testers, the Cohen's kappa coefficient was calculated (0.91).

2.5.2 The Torrance tests of creative thinking (TTCT)

The TTCT developed by Torrance (1966) was used to measure the creativity of children and adapted to Turkish by Aslan (2001). The TTCT can be administered to individuals or to groups from kindergarten onwards. The TTCT contains two versions, Figural and Verbal, and two parallel forms, A & B. While the figural test has three subtests, picture construction, picture completion and parallel lines, the verbal test contains seven subtests. For this study, a TTCT figural test was used, with the tester inviting the children to enjoy the activities and to view the tests as a series of fun activities. Test reliability was obtained using Cronbach's alpha .71 (Aslan, 2001) and .70 for the current study.

2.5.3 Evaluation instrument for the early mathematical reasoning skills (EIEMRS)

The Evaluation Instrument for the Early Mathematical Reasoning Skills was developed by Ergül (2014) to measure kindergarteners' mathematical reasoning skills.

EIEMRS consists of a total of 40 questions, two sub-tests measurements, and data analysis probability. EIEMRS is administrated through individual child interviews and children's responses are recorded by scoring between 0 and 5. The test-retest reliability of the EIEMRS was .98 (Ergül, 2014; Ergül & Artan, 2015). The calculated Cronbach's Alpha was .85 and interrater reliability of Cohen's Kappa was .85 indicated very good agreement.

2.5.4 Problem-solving skills scale (PSSS)

The PSSS was developed by Oğuz and Köksal-Akyol (2015) to measure 60–72-month-old children's problem-solving skills. The scale is based on 18 age-appropriate problem statements presented as verbal prompts, as well as statements in relation to pictures. Answers provided by the children are scored within a range between 0 to 4, with 0 indicating no answer and 4 indicating the correct answer. Final scores are then tabulated by adding together the total response points of each respective children. Cronbach's alpha reliability of PSSS was calculated as .86 (Oğuz, 2012; Oğuz & Köksal-Akyol, 2015). For the current study, the Cronbach's alpha reliability was calculated as .84 and interrater reliability Cohen's kappa was .86 indicated very good agreement.

2.5.5 Head-toes-knees-shoulders (HTKS)

The HTKS tool was developed by Ponitz, McClelland, Jewkes, Connor, Farris and Morrision (2008) to measure children's behavioral regulation using a structured observation that requires children to perform the opposite of a dominant response using four different oral commands, (e.g., the children are asked to touch their heads when the interviewer says "touch your toes"). HTKS contains 20 tasks measuring behavioral self-regulation and executive function, with the activity occurring over a five-to seven-minute time frame. Ivrendi (2011) adopted HTKS for use with Turkish children and found that it is valid and reliable tool. In the current study, Cronbach's alpha was calculated as .91 and interrater reliability, Cohen's kappa was .81 indicated very good agreement.

2.6 Data collection

Prior to data collection, the head researcher received five different trainings about the measurement tools used in the study, and then she trained three other graduate students on the correct procedures for administrating each test to the participating children. During this training period, the test items, materials and procedures were explained, and the testers had several opportunities to administer tests to the children who were not participated in the research project. All children completed each measurement tool in the same order: (1) TTCT, (2) TELD-3, (3) EIEMRS, (4) PSSS, and (5) HTKS. Before testing, ice-breaker activities were held so that children would feel comfortable with the testers. After that, the children were instructed that their information and assistance were needed to answer some questions. Research data were obtained only from those who volunteered. While administering the TTCT, groups of children were required to sit an appropriate distance from one another to prevent individuals from being affected by the drawings and responses of the other participants. The children were given paper and crayons and asked to drawn pictures based on the TTCT's instructions. The completion of the test lasted for about an hour. The rest of the tests were individually administrated in a quiet room in the school based on the test's own instructions. Each child had one test a day, and administration of a test lasted for approximately 5–35 minutes.

2.7 Data analysis

Statistical analyses had three phases: (1) the children's standard scores from the pre and post-tests were calculated and tested for normality. A distribution is called approximate normal if skewness or kurtosis (excess) of the data are between −2 and + 2 (George & Mallery, 2013). In the current study, the kurtosis and skewness of the data were between −.40 and 1.94, and these values were enough for determining considerable normality; (2) the Paired Samples T-test was performed to compare the scores of the children in the pre-tests and post-tests; (3) to examine the differences between the experimental and control groups, the Independent Samples T-test was conducted.

3 Findings

3.1 Comparison of the experimental and control groups' pre-test scores

The independent samples t-test was used to determine differences in the children's scores on language, cognitive, and creativity skills between the experimental and control groups, and the results were presented in Table 1.

As seen above, the pre-test scores of the children in the experimental and control groups did not significantly differ for language test ($t_{77} = -.023$; $p > .05$), creativity ($t_{78} = 1.809$; $p > .05$), problem solving skill ($t_{78} = .667$; $p > .05$), the early mathematical reasoning skills ($t_{78} = 1.417$; $p > .05$) and the self-regulation skills ($t_{78} = -.890$; $p > .05$). These results indicated that the children in the experimental and control groups had similar developmental characteristics before the coding intervention.

3.2 Comparison of the experimental and control groups' post-test scores

At the end of the nine weeks of PCP intervention, Independent Samples T-test was also conducted to compare the children's post-test scores. The results are presented in Table 2.

The results showed that there were significant differences between the children's post-test scores of language ($t_{77} = 5.076$; $p < .05$), creativity ($t_{78} = 4.33$; $p < .05$), problem solving ($t_{78} = 5.937$; $p < .05$), early mathematical reasoning skill ($t_{78} = -6.506$; $p < .05$) and self-regulation skill ($t_{78} = 2.793$; $p < .05$). This difference was in favor of the experimental groups. In other words, according to the developmental scores

Table 1 Comparison of the groups' language, cognitive, and creativity pre-test scores

Variables	Groups	n	$\overline{X}$	ss	df	t	p
TELD-3	Experimental	39	100.69	10.46	77	−.023	.982
	Control	40	100.75	11.58			
TTCT	Experimental	39	31.59	14.52	78	1.809	.074
	Control	41	25.88	13.72			
PSSS	Experimental	39	24.77	6.25	78	.667	.507
	Control	41	23.78	6.97			
EIEMRS	Experimental	39	112.26	21.58	78	1.417	.160
	Control	41	105.29	22.34			
HTKS	Experimental	39	24.56	10.79	78	−.890	.376
	Control	41	26.68	10.51			

$^*p < .05$

measured by all five instruments, the children in the experimental groups had higher scores than those in control groups at the end of the 9-week PCP intervention.

3.3 The effects of PCP intervention on children's cognitive, language and creativity skills

Results of the Paired Samples T-tests were computed to examine the differences between the pre and post-test scores of the children's language, cognitive, and creativity skills and are shown in Table 3.

Following the nine-week PCP intervention, there were significant differences between pre-test and post-test scores on language, creativity, and cognitive skills scores of the children in the experimental group. The results indicated that the children's post-test scores significantly increased after the 9-week PCP

Table 2 Comparison of the groups' cognitive, language and creativity post-test scores

Variables	Groups	n	$\overline{X}$	ss	df	t	p
TELD-3	Experimental	39	116.05	7.22	77	5.076	.000*
	Control	40	105.90	10.26			
TTCT)	Experimental	39	51.51	20.04	78	4.33	.000*
	Control	41	31.80	17.15			
PSSS	Experimental	39	34.72	10.41	78	5.937	.000*
	Control	41	23.05	6.90			
EIEMRS	Experimental	39	141.46	24.05	78	6.506	.000*
	Control	41	108.39	21.40			
HTKS	Experimental	39	34.03	5.83	78	2.793	.007*
	Control	41	29.22	9.12			

$^*p < .05$

intervention. These research results imply that PCP activities positively contribute to children's language, cognitive, and creativity skills.

The same Paired Samples T-tests were computed to examine whether there was a significant difference between pre and post-test scores of the children in the control group. Interestingly, the findings revealed that there were significant differences in children's both language ($t_{39} = -2.94$; $p < .05$) and creativity scores ($t_{39} = -2.36$; $p < .05$). By contrast, the children's cognitive scores showed statistically insignificant results. To examine the analysis of variance for both experimental and control groups' language and creativity pre and post-test scores, the General Linear Model (GLM) analysis was employed. The results of the GLM analyses, using TELD-3 as the dependent variable and experimental/control groups and the pre/post-tests as independent variables, yielded a significant overall model for the groups ($F_{(1;77)} = 22.83$; $p < .01$). See Fig. 4.

In the Fig. 4, a profile plot of experimental groups shows that the estimated marginal means were significantly increasing more than they were for those of the control groups. Although the language scores of the children in both groups increased in the post-test, the level of increase in the experimental group was found to be significantly higher than the control group. Similarly, GLM was conducted using TTCT as the dependent variable, with the experimental/control groups and the pre/post-tests as independent variables, providing a significant overall model ($F_{(1;78)} = 11.14$; $p < .05$). See Fig. 5.

The above figure indicates that the estimated marginal means of the experimental group displayed significantly more increase than the control group. Although the creativity scores of the children in both groups increased in the post-test, the level of increase in the experimental group was found to be significantly higher than those in the control group.

Table 3 Comparisons of the pre-test and post-test scores of the experimental and control groups

Pretest				Posttest				
	N	Mean	Sd	Mean	Sd	*df*	*t*	*p*
Experimental Group								
TELD-3	39	100.69	10.46	116.05	7.22	38	−12.661	.000*
TTCT	39	31.59	14.52	51.51	20.04	38	−5.865	.000*
PSSS	39	24.77	6.25	34.72	10.41	38	−6.027	.000*
EIEMRS	39	112.26	21.58	141.46	24.05	38	−12.76	.000*
HTKS	39	24.56	10.79	24.56	10.79	38	−6.21	.000*
Control Group								
TELD-3	41	100.75	11.58	105.90	10.26	39	−2.94	.005*
TTCT	41	25.88	13.72	31.80	17.15	40	−2.36	.023*
PSSS	41	23.78	6.97	23.05	6.90	40	.783	.438
EIEMRS	41	105.29	22.34	108.39	21.40	40	−1.34	.188
HTKS	41	26.68	10.51	29.22	9.12	40	−1.46	.150

*$p < .05$

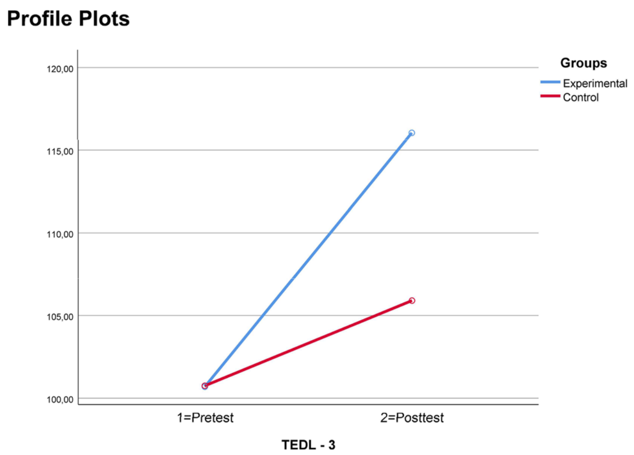

Fig. 4 Comparisons of the experimental and control groups' TEDL-3 scores

4 Discussion

The current study investigated the effects of the PCP intervention on children's development and revealed important findings about young children's cognitive, language, and creativity skills. First, participating PCP activities measurably improved children's cognitive, language, and creativity skills. The main reason for this was that PCP is an integrated program that blends coding with everyday curriculum-based early childhood learning activities such as language and literacy, arts, science, math, and play. The overall integrated philosophy of PCP enabled the children to naturally engage in meaningful and appropriate coding activities and gave various opportunities to discover the coding skills in a playful environment. These findings align with growing evidence that participating in meaningful coding activities can increase children's cognitive and socio-emotional skills (Bers & Resnick, 2017; Papadakis et al., 2018a). In addition, engaging in discovery and play-based developmentally appropriate coding activities positively affects children's observation, design, and evaluation skills (Altin & Pedaste, 2013).

A close examination of the research findings indicates several important factors. First, PCP has enhanced the participant children's problem-solving skills. Previous studies have demonstrated that coding education supports the problem-solving skills of young children (Akyol-Altun, 2018; Aydın, 2019; Bers et al., 2014; Di Lieto et al., 2017; Fessakis et al., 2013; Tatlısu, 2020). PCP activities such as "there is a mistake here, let's overcome" are specifically designed to support children's problem-solving skills positively and certainly contributed to these increases. Flórez et al. (2017) stated that this positive effect on problem-solving skills is due to the fact that coding training includes the ability to design algorithmic plans. Similarly, Bers et al. (2014) revealed that robotics education supports young children in solving the problems they encounter by doing debugging. In other words, PCP enabled children to solve problems actively and creatively.

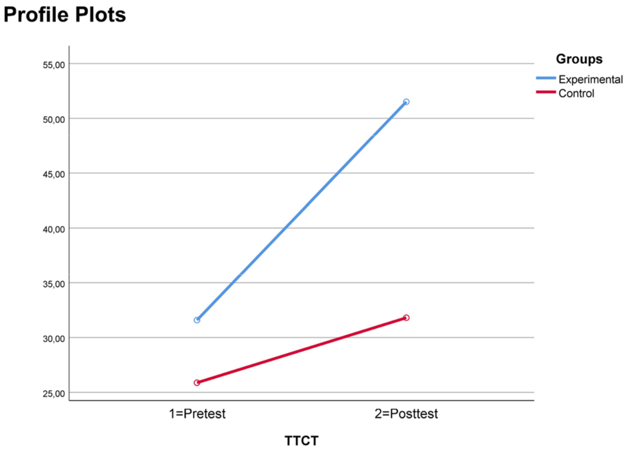

Fig. 5 Comparisons of the experimental and control groups' TTCT scores

Secondly, this study revealed that PCP has significantly increased children's early mathematical reasoning skills. PCP activities directly targeted sorting, algorithmic thinking, prediction, comparison, and cause and effect relationship skills. Research studies have revealed similar results, indicating that coding and robotics education significantly supported children's early mathematical reasoning skills (Blanchard et al., 2010; Caballero-Gonzalez et al., 2019; Di Lieto et al., 2017; Flannery et al., 2013; Kazakoff et al., 2013). Particularly, Savard and Highfield (2015) explained that coding is directly related to using mathematics. To code a robot for performing certain tasks, children were required use the mathematical reasoning skills. Additionally, recent research findings supported that using apps and mobile devices in early childhood classrooms improved children's mathematical thinking skills by enabling them to use mathematical concepts actively and effectively (Outhwaite et al., 2019; Papadakis et al., 2018b; Schacter & Jo, 2017).

Thirdly, the results showed that PCP supported children's self-regulation skills. Participating children who learned to code improved in inhibitory control, working memory, and attention skills. This result is also aligned with previous research that showed coding and robotic education improved children's self-regulation skills (Di Lieto et al., 2017; Kazakoff, 2014). PCP activities required the children to mentally predict, to achieve certain goals, and to select appropriate commands to move the robots. In a similar study, Di Lieto et al. (2017) stated that children's working memory and inhibitor control were supported as they were asked to fulfill a goal, find new solutions to solve the problem without time limitation, or to create new ways to address a problem based on a certain rule. During PCP, the children engaged in finding a goal, creating a plan to achieve it, executing their plans, evaluating the results, and fixing any mistakes. Bers (2020) emphasized that this repetitive design process was an important factor supporting self-regulation skills.

Fourthly, participating in PCP increased children's language development. PCP activities allowed children to express themselves, discuss, communicate, and collaborate with their friends. During PCP activities, the children were required to work in small groups, and in block coding activities children worked in pairs. Under the environmental awareness theme, the children read stories and created their own stories that were then used to code the robots using block coding with Scratch Jr., thereby creating a language-rich environment for the children. A recent meta-analysis study revealed that learning robotics has a positive effect on children's cognitive, conceptual, language, and collaborative skills (Toh et al., 2016). In line with Sugimoto (2011), this study revealed that children's participation in telling and creating stories using robots had a positive effect on language development. PCP provided the children supportive opportunities such as creating their own stories and sharing their stories and thoughts with their friends. As Bers et al. (2019) and Lee et al. (2013) maintain, actively coding and engaging in robotics activities directly supported children's language development.

Lastly, the results indicated that participating PCP activities significantly increased the children's creativity scores. The children's participation in PCP activities engaged creative thinking skills in different ways. For example, during the block coding activities with Scratch Jr., the children planned, created, and coded their own stories and recorded their voices. Throughout the course of the study, developmentally appropriate PCP activities allowed for children to create their own content and own games. Again, the unplugged coding activities enabled the children to actively use their creative thinking skills while making their own robots and coding the movements and actions of these robots. Previous research findings have also demonstrated that coding and robotics education has a positive effect on fostering children's creativity skills (Papadakis et al., 2018b; Pardamean, 2014; Resnick, 2003; Siper-Kabadayı, 2019; Sullivan & Bers, 2018; Sullivan et al., 2013). Likewise, recent research emphasized that open-ended designs encouraged creativity in children and, as a result, improved children's problem-solving skills (Dow & Mayer, 2004; Sullivan, 2017; Yıldırım, 2018).

This study has explored the effects of the PCP on children's cognitive, language, and creativity skills. The findings displayed that the PCP can be an effective curricular strategy for developing children's cognitive, language, and creative skills. Considering this finding, it is important to provide children more opportunities to engage with developmentally appropriate and hands-on coding and robotics education that is integrated into the daily curriculum of early education. To achieve the benefits of coding education for young children, early childhood education teachers must play crucial roles in integrating coding and robotics activities into their daily curriculum. Unfortunately, current early childhood teachers are not being provided with the types of knowledge and skills required to integrate coding education into their curriculum. Simply put, basic training for them is necessary. Therefore, workshops, seminars, and videos that provide concrete activity examples must be made available and accessible for early childhood teachers. Like the PCP, other integrated and hands-on programs can be prepared for teachers to use in their classroom. Standards about appropriate coding education can be defined by experts who specialize in both coding and robotics education and early childhood education. With the establishment of clear standards and expectations, early childhood teachers will be to integrate coding and robotics education into their daily curriculum (Bers et al., 2019).

In addition to teacher training, robots and other tangible materials are necessary for the effective integration of coding and robotics education into early education. Some Turkish early childhood teachers are reluctant to integrate technology into the curriculum because they believed the cost of such materials to be prohibitive for the classrooms (Uyanık-Balat & Günşen, 2017). For this reason, early childhood education teachers should be informed about unplugged coding, with which they can teach basic coding skills to children without computers or tablets. This way, teachers who face a lack of available resources will be able to plan and provide unplugged coding activities for their children.

Finally, the PCP and similar programs provide the context for children to have more control over the ways technology interacts with their daily lives, such that they move from merely being consumers of technology to makers of technology. This shift in how one locates and understands their relationship to technology holds the potential to create a qualitative difference in the lives of children, with effects that go beyond the classroom. Employing an integrated, child-centered curriculum enables children to see a pathway in life that involves a relationship between critical thinking and self-regulation incorporated with the practices of science, technology, engineering, and mathematics. Understanding and amplifying this relationship is increasingly relevant in a world where global labor markets have no real boundaries outside of the ubiquitous presence of coding and robotics technology. Indeed, one can argue that a more meaningful measure of geopolitical boundaries can be marked by those countries that are standardizing the implementation of coding and robotics education across their entire curricula. As suggested above, opportunities to coding and robotic education are too often only available through private education, thereby exacerbating and reproducing structural impediments to equitable educational outcomes for all children. Thus, one of the goals in conducting this study has been to contribute to ongoing discussions about the importance of including coding and robotics education as part of a broader national curricular effort to prepare and provide all children, regardless of parental socio-economic status, with the skills necessary for success in the twenty-first century.

4.1 Limitations and future directions

Although this research points to many important findings and results, it has some limitations. First, a limited number of children were included in the study group due to insufficient resources. This situation limits the generalizability of the findings to large samples so that conducting this research with bigger groups will be valuable. Future research studies can train early childhood teachers about the PCP and examine the effects of the PCP on a large number of children. Moreover, the PCP included three parts named as unplugged coding, robotics, and block coding activities. Further studies can separate the effects of the different activities on children's development. In this study, the effects of the PCP on cognitive, language, and creative skills were examined. Future studies can examine other areas of development including the socio-emotional domain.

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Data availability The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical approval The reported study complies with the American Psychological Association's ethical standards in the treatment of participants and was approved by the Social Sciences Research Ethical Review Board of the Pamukkale University, Denizli TURKEY and Ministry of National Education (MoNE) Directorate of Primary Education.

Informed consent Informed consent was obtained from all participant parents included in the study.

Competing interests/Conflict of interest The authors declare that we have no conflict of interest.

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