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The Effects of a Robotics Program on Preschool-Students' Creative Thinking Skills*

Gamze SİPER KABADAYI, Duygu SÖNMEZ*****

Article Information	**ABSTRACT**
Received: 15.03.2024 *Accepted*: 10.07.2024 *Online First*: 30.07.2024 *Published*: 31.07.2024	Robotics education is considered a valuable tool for the development of cognitive and interpersonal skills. It is highly valued as a part of STEM education as it allows a collaborative learning environment that supports skills such as creativity, critical thinking, algorithmic thinking and problem solving. Considering the value of robotics education, a robotics program was developed using the STEM framework. This study investigates the effects of this STEM-based educational robotics program on preschool students' creative thinking skills. A mixed design approach was utilized for the study. The Torrance Creative Thinking Test was used before and after the program as well as one-on-one semi-structured interviews to investigate students' creative thinking. Results of the study suggest that the participants' creative thinking general scores and fluency subscale scores increased significantly. In addition, it has been observed that students were able to establish relationships between concepts during the program and reflected algorithmic thinking skills in their designs. **Keywords:** STEM education, educational robotics, early childhood education, creative thinking skills, algorithmic thinking skills

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1. INTRODUCTION

In today's world there is a significant momentum in the development of knowledge accompanied by advancements in science and technology. The time period we are living in is called the "information age" due to the advancements in information technologies. Just as the Industrial Revolution, which was the period before the information age, we are seeing the effects of information technologies in every aspect of our daily lives, economic and social structure. In the current global economy, knowledge is the power rather than the material products of an industrial society (Kocacık, 2003) and countries are racing to invest in sectors that can give them an edge in the global race.

Education is one of the powerful tools countries utilize to prepare their citizens for the future by helping them acquire necessary knowledge and skills. Today these essential competencies are referred to as 21st-century skills, encompassing critical thinking, creativity/innovation, problem-solving, collaboration, and communication. In the information age we live in, literacy of information technologies is a must. And such literacy requires individuals to be creative, questioning and innovative. Aligned with the developments and expectations of the changing world, the education system transforms accordingly, looking for best approaches and policies which would assure excellence in education. Some of the recent approaches that gained popularity in education include problem-based learning, STEM education and robotics. These approaches are reported to have a positive influence on students' confidence in technology use, learning, understanding how science and technology is utilized in solving real-world problems, orientation towards professions in science-related fields, and the ability to take part in collaborative teamwork (Eguchi, 2016). In light of these benefits, the overall premise of these approaches is to prepare individuals for the future with the skills they would need. Robotics education has become popular in recent years with the emphasis given to STEM education. Since robotics create opportunities for individuals to cultivate skills such as creativity, algorithmic thinking and problem solving (Eguchi, 2016) its popularity has increased. Robotics is considered one of the most promising parts of STEM education, as it covers various fields of knowledge (science, mathematics, languages, technology, and engineering). As stated, educational robotics also supports problem-solving skills on which the STEM paradigm is based. Students can also learn

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** PhD Student, Hacettepe University Institute of Educational Sciences, Ankara-TÜRKİYE. e-mail: gamze.siper@hacettepe.edu.tr (ORCID: 0000-0001-5827-4483)

*** Assoc. Prof. Dr., Hacettepe University, Faculty of Education, Department of Mathematics and Science Education, Division of Science Education, Ankara-TÜRKİYE. e-mail: dsonmez@hacettepe.edu.tr (ORCID: 0000-0001-7821-6344)

concepts in computer science and robotics with the help of educational robotics (Bers, Flannery, Kazakoff, & Sullivan, 2014). In a study conducted with primary school students, it was revealed that robotic activities created an entertaining and creative educational environment that effectively developed skills such as problem solving and computational thinking (Atmatzidou and Demetriadis 2016). In addition to 21st century skills namely critical thinking and problem solving, elements of robotics education in elementary schools allows students to improve their technical and mechanical knowledge and apply all these skills into practice (Rakhmanina et al 2022). The majority of the research on this subject emphasizes that robotics plays a positive role in learning content, developing creative thinking and developing problem-solving skills. In a study conducted with preschool children, it was revealed that children were actively and successfully involved in discovering and creating robot behaviors in a fun learning environment (Mioduser and Levy, 2010). Furthermore, interaction with robotics is reported to positively affect students' motivation and attitude (Karim, Lemaignan & Mondada, 2015). Educational robotics has been proven to increase students' interest in STEM fields. Considering countries' efforts to develop an interest among youth towards STEM related careers that is an important positive outcome of robotics education (DeWitt & Archer, 2015; U.S. Congress Joint Economic Committee, 2012). Moreover, it has been revealed that applied and project-based learning processes provided by educational robotics competitions have long-term effects on students' learning and motivation (Eguchi, 2016). Robotics can easily be implemented in teaching and learning processes at all grade levels starting from early childhood education. A study conducted with preschool children revealed that students' self-confidence increased, and they learned programming (Stoeckelmayr, Tesar, & Hofmann, 2011). Children working with robots not only sit in front of a computer but also develop their fine motor skills while manipulating robotic objects (Sullivan, Kazakoff, & Bers, 2013). Studies conducted on educational robotics in early childhood indicates that students can acquire fundamental engineering and programming concepts as well as establish skills in logical sequencing and understand cause-effect relationships (Elkin, Sullivan, & Bers, 2016). In other words, when applied to young children, robotics supports motor skill development. Literature suggests that any investment in early childhood education would be more beneficial in comparison to other grade levels (Heckman, 2011). Considering the benefits, integration of educational robotics in early childhood education would be beneficial to support creativity and problem solving while creating an interest in STEM fields among children. Despite early childhood education's underrepresentation in STEM education reports and global initiatives, this study may demonstrate early robotics education's potential and applicability in terms of the integration of STEM fields (Çetin & Demircan, 2018). With these premises in mind this study focuses on using a STEM based robotics education program developed by authors in early childhood education and investigates programs' effect on students' creative thinking skills and investigates how robotics program affects students' creative thinking skills, design abilities and students' perception of the robotics program.

Research Questions investigated during the study were "What is the effect of the robotics applications program, which is a STEM education approach and prepared for preschool students, on students' creative thinking skills?"
Sub problems.
1. How does the robotics program affect preschool students' creative thinking skills?
2. What is the effect of the robotics program on preschool students' creative thinking skills in terms of gender?
3. What is the effect of the implemented robotics program on preschool students' designs?

1.1. STEM Education

Aligned with the developments in knowledge and technologies, the definition of skills for future workforce has transformed as well. These changes lead to the emergence of new paradigms and understandings in the field of education such as STEM education. The integrated nature of STEM education enables learners to work in collaborative groups while discovering real-world problems and to gain extra-curricular skills through combination of two or more disciplines (Havice, 2015). STEM activities can be structured on a problem or a project and include group activities and laboratory research which allow individuals to develop necessary 21st century skills and help to become citizens who can make better decisions on global and local issues such as sustainability, personal health, environmental quality, energy efficiency, and responsible resource use (Bybee, 2010). Integrated STEM education breaks the barriers between disciplines and allows students to experience how science, mathematics, technology and engineering are connected to each other.

The 21st century brought new definitions of required skills as we are living in a more competitive world. Individuals are expected to be better in many skills such as communication, collaboration, problem solving and so on, so that they can meet the demands of this very complex world we live in and the future. All these required skills are defined in the 21st century learning framework which was developed as a unified vision. The skills should be implemented in the core academic subjects in an integrated manner and includes three groups of skills interconnected with each other and core subjects which are supported by standards and assessment, professional development, curriculum and instruction, and learning environments (P21, 2009).

The three groups of skills defined by the 21st Century Learning Framework are

• Life and career skills: Flexibility and adaptability, initiative and self-management, social and intercultural skills, productivity and accountability, leadership and responsibility skills
• Learning and innovation skills: creative thinking and innovation, critical thinking and problem solving, communication and collaboration skills
• Information, media and technology skills: information and media literacy" (2019, Battelle for Kids, p2)

These skills are identified as necessary for individuals' success in the workforce as well as social life for future generations. Individuals who possess these skills are expected to contribute more to commerce and civic life in the digital economy of the 21st century (2014, Kivunja). There is a natural match between 21st century skills and STEM components. According to Bybee (2010), all STEM disciplines offer opportunities for students to acquire 21st century skills, because each of the STEM components plays a crucial role in the development of technologies and innovations.

In STEM education using a real-world problem allows students to make necessary connections between the content and the world we live in through either as a context or relevance. Especially, relevance can be a motivating factor for students (Dare et al, 2021).

1.2. Educational Robotics

Our current understanding of robotics has evolved significantly in the last 7 decades in comparison to early versions of robots which were built in the 1950s. The Robot Institute of America (1979) provides a definition of robots as "a reprogrammable, multifunctional manipulator designed to move material, parts, tools, or specialized devices through various programmed motions for the performance of a variety of tasks." Advancements in robotics, such as soft-bodied robots, robots in different sizes even in micro scale and functioning in various ways and environments, led to robots having a significant existence in our daily lives. Such existence creates the need for a solid understanding of STEM disciplines and robotics as the nature of the workforce and social life is changing accordingly. Educational robotics is defined by Eguchi, (2015) as "a transformational tool for learning, which promotes learning of computational thinking, coding, and engineering as critical ingredients of STEM learning to prepare students for the technology-driven future" (cited in Rapti & Sapounidis, 2023). Educational robotics is suitable for all grade levels (Alimisis, 2003) and has become the new generation of traditional materials such as pattern blocks, beads and balls (Brosterman, 1997). Robotics education gained a notable interest from the education community as it supports development of cognitive and interpersonal skills (Alimisis, 2003) through active learning environment and hands-on activities which aids in students' interests, imagination and curiosity (Eguchi, 2010). According to Catlin (2016), educational robotics becomes a suitable tool when it is motivating students to the lesson or in small-scale problem-solving tasks, aiming to teach coding skills, supporting collaboration, and use of different ideas. Therefore, educational robotics kits are considered a versatile teaching tool for all ages and disciplines. Robotics education is considered effective in STEM education since it creates an opportunity for students to explore concepts such as gears, levers, motors and sensors in a concrete way. In addition, through projects students learn STEM concepts in a fun, motivating and creative way (Bers et al., 2006).

As an alternative tool for the adoption of the STEM approach, educational robotics provides an environment where students can learn different aspects of science, mathematics, computer science and engineering (Stripling & Simmons, 2016). Students acquire different skills by using educational robotics, such as algorithmic thinking skills (Repenning, Webb, & Ioannidou, 2010). According to Futschek (2006), algorithmic thinking encompasses the capacity to analyze problems, identify their core issues, determine essential steps for solving them, devise accurate algorithms, and consider various scenarios related to the problem. These abilities identified by Futschek (2006) are the basis of programming. Educational robotics is not limited to just teaching basic programing logic but also mathematics through mathematical problem solving with coding (Papert, 1980). It offers opportunities to deal with content in informatics, practice problem solving skills and exercise fine motor skills and eye-hand coordination. Through integration of non-STEM fields, it allows development of early literacy skills and engagement in the arts (Bers, Flannery, Kazakoff, & Sullivan, 2014). Educational robotics can be implemented in different grade levels to teach abstract concepts through concrete examples. Students can successfully, understand, design and program robots to perform specific tasks in early childhood education with the implementation of educational robotics into teaching which leads to a positive effect on students' "sequence" skill scores (Mioduser & Levy, 2010; Sullivan, Kazakoff, & Bers, 2013).

Educational robots such as Bee-Bots which were used in elementary education by Athanasiou, Topali, & Mikropoulos (2016) allows students to use reflective thinking processes by providing rapid feedback enabling students to make corrections and optimize their coding. These examples show the potential of educational robotics in connecting abstract knowledge to a real-world context. Educational robotics also supports collaborative work. In a study conducted with Snap4Arduino with the participation of students aged 8-10, teamwork and collaborative learning were observed in students. In addition, all students identified programming as a valid learning method (Pina & Ciriza, 2016). Benefits of educational robotics are not limited to early childhood education and apply to K-16 grade levels. They create an enjoyable and motivational learning environment which helps students gain programming and algorithmic thinking skills in addition to creative thinking, collaboration and problem-solving skills (Janka, 2008).

1.3. Importance of Early Childhood Education

Early childhood, which is from birth to the age of seven, is considered a critical stage for the development of the individual in all aspects. During this period, the individual develops rapidly and his intelligence, perception, personality, social behaviors, communication skills, emotional control and mental abilities are shaped. The development of these skills forms the basis of the characteristics that will reflect the character of the child throughout his life (Oral, Yaşar & Tüzün, 2016). Early childhood education provides a positive support to the individual in this developmental stage. This educational process forms the basis of the individual's abilities and skills, and it is shown that benefits of investing in early childhood education are higher than any other grade levels since the development rates of individuals during this period are quite high and the investment costs for this period are low (Heckman, 2011). According to Heckman (2011), who has done important studies on economics, education creates a positive effect on skill acquisition during the early childhood period and these skills feed and support each other. During this time, it is easier for the individual to acquire the characteristics that he will use in the future, as well as emotion control, perseverance, self-consciousness and social skills. These skills are the most important tools for success in school as well as career including increase in productivity, a healthy lifestyle and social life, better wages, and less tendency for crime (Heckman, 2011). In this context, the early childhood period, which is the most critical period of education, greatly affects the future perspectives and lives of individuals. For this reason, every study done in early childhood functions as a magnifying mirror for the future. In this period when the development processes of individuals are most intense, the individual develops as much as his environment allows.

1.4. Creativity

Creativity is one of the 4C's of 21st century skills accompanied by critical thinking, communication and collaboration. Creativity can be learned, and teachers are encouraged to create learning environments fostering creativity and innovation. Creativity not only helps students to identify their own capacities but is also highly regarded in economics, job market and social life (Savedra & Opfer (2012). According to the Future of Jobs Report (World Economic Forum, 2020) identifies top 15 necessary skills for 2025 and creativity is one of them. These skills are ; "1) Analytical thinking and innovation, 2) Active learning and learning strategies, 3) Complex problem solving, 4) Critical thinking and analysis, 5) Creativity, originality and initiative, 6) Leadership and social influence, 7) Technology use, monitoring and control, 8) Technology design and programming, 9) Resilience, stress tolerance and flexibility, 10) Reasoning and problem solving and ideation, 11) Emotional intelligence, 12) Troubleshooting and user experience, 13) System analysis and Evaluation, 14) Service Orientation and 15) Persuasion and negotiation" (p. 36). Current and predicted economic dynamics show that production relies on innovation and design and they both rely on a creative perspective for success.

Defining creativity can be challenging due to its susceptibility to various interpretations. According to Piirto (2011) creativity is a skill which is across all domains not just art and it's a prerequisite of innovation. May (1994) defined creativity as the encounter of a concentrated person with his own world. The process of looking from a different perspective and producing new ways is common in all accepted definitions. Creativity emerges from one's experiences and it's a way of seeing connections in the material world we live in. It helps us to shape our futures and lifestyles (Brandt & Eagleman, 2017). Creativity and innovation have an important place in the STEM paradigm as it allows multiple ways of thinking through integration of STEM and non-STEM disciplines.

2. METHODOLOGY

2.1. Robotics Program and Participants of the Study

This study investigates the effects of a STEM-based robotics program on children's creative thinking skills with a mixed design approach. For this purpose, a robotics program was developed for early childhood education. The robotics programs consist of six modules; (What is a Robot, Let's Make a Robot Model, How Does a Robot Work? How Do We Make Computers Do What We Want?, Let's Meet Our Robot, Let's Develop Our Robot) and aims to develop an understanding about robots and teach algorithmic thinking skills and the connection between concepts. Some of the components of the robotics program include design processes, puzzles, circuits, coding and how robots move. A programmable robot was integrated into modules as a part of the program to teach coding blocks and to provide algorithmic thinking skills. This programmable robot allows integration of the LEGOs and was also used to support students' design processes. The robotics program is aligned with the Ministry of National Education's Preschool Curriculum and uses the 5E model. During the development of the program two content experts were consulted to review the modules and provide feedback. A pilot study was conducted with the participation of 4 students to evaluate the program. Based on the findings of the pilot study the robotics program was revised and each module was restructured to be 30 minutes in length.

The final version of the robotics program was implemented by one of the researchers for 10 weeks outside of the classroom time during the spring semester of the school year. Participants of the study were 8 students, four girls and four boys, attending a private kindergarten in a major city in Türkiye. The students participating in the robotics program were six years old and had not participated in any educational robotics training or program prior to this study. All students come from middle- and high-income families and both parents of all students either hold an undergraduate or graduate degree. Participation in the developed robotics program was on voluntary basis with parents' consent.

2.2. Instrument and Data Collection

During the study for the data collection purposes Torrance Test of Creative Thinking, semi structured interviews, students' drawings and video recordings were used. Torrance Test of Creative Thinking (TTCT) was used to investigate the effects of the robotics program on students' creativity. TTCT was developed by Paul Torrance in 1966. The test consists of two parts: "creative thinking with words" and "creative thinking with pictures". The A and B forms of the test contain the same activities. TTCT includes five subscales: originality, fluency, elaboration, resistance to premature closure and abstractness of titles. The reliability of TTCT test is reported as .86 and the reliability coefficients for subscales are 0.82, 0.78, 0.51, and 0.78 for fluency, flexibility, originality and elaboration respectively. (Torrance, 1972).

The “thinking creatively with pictures” part was used during this research which comprises three activities: picture creation, picture completion, and lines (booklet A) or circles (booklet B). The test is evaluated on five different subscales: fluency, originality, elaboration, abstractness of titles and resistance to premature closure. An individual with fluent thinking skills generates many ideas with drawings and common objects, arranges blocks and other play materials in many combinations, easily assembles complex machines, easily draws maps from memory, and organizes objects and materials in three-dimensional space. An individual with unique or original thinking skills produces unusual and extraordinary solutions to problems that others have not thought of. Enrichment, one of the sub-dimensions of creative thinking skills, is a dimension related to imagination. The sub-dimension of giving abstract titles to works, which is a characteristic of the creative individual, shows how deeply and abstractly he reflects a concrete situation. Resistance to premature closure shows how open the individual can keep his mind (Torrance, 1972).

During the study the Turkish version of TTCT which was adapted by Aslan (2001) was used. During the adaptation process of the TTCT, Aslan (2001) collected data from pre-school, high school and university students and reported the Turkish version of the TTCT as a reliable instrument for all age groups. As a result of the validity analyzes, significant results were obtained at the $p<0.01$ level for all age groups and all score types of the verbal creativity test. In terms of total figural creativity scores, the highest mean fluency score in the preschool group was obtained ($x = 20.91$, $n = 231$), and the lowest mean was obtained for the abstractness of the titles ($x = 2.14$, $n = 231$). Since the preschool group was illiterate, a verbal test was not applied for the kindergarten age group, and figural creativity reliability coefficients were obtained. The lowest score of the group was determined as Cronbach's alpha value (.50) and the highest internal consistency coefficient was determined as (0.71). Since the sample size was limited to eight participants in the current study, reliability analyzes were not repeated. However, two experts independently scored each students’ tests and scores were compared to assure inter-rater reliability.

Semi- structured interviews were conducted to understand how participants perceive robots and the effects of the robotics program on students’ knowledge and understanding. For this purpose, interviews were conducted before (interview I) and after (interview II) the program. Interview questions were developed by the researchers and two external experts provided feedback to maintain content validity. Interview I aimed to reveal students' perspectives and knowledge on robots and their previous experiences on this subject. Interview II specifically focused on student’s achievements from the program and different scenarios were used to investigate students’ algorithmic thinking skills as well as to understand how they connect concepts with each other. Students were asked to solve a problem or asked to design a program, including necessary steps, based on given complex scenarios as well as to comment on their experiences regarding the robotics program. Some of the interview questions were as follows; What is a robot? What are the features of a robot? Based on the (given) scenario, if I want my robot to move forward then stop and turn itself off, what kind of features and programs would I need? In addition to the interview data, students’ pre and post drawings were used to analyze design processes and students were carefully observed and lessons were videotaped throughout the program to enable retrospective analysis.

2.3. Data Analysis

The quantitative data collected with TTCT was analyzed to explore the effects of the robotics program on students’ creative thinking skills and gender differences using Wilcoxon signed rank and the Mann Whitney U Tests. Due to the small number of participants, non-parametric analyzes were used. Total TTCT scores and subscale scores were analyzed using SPSS 23.0 software. The qualitative data collected through interviews, students’ drawings and video recording were analyzed using content analysis after interview data and video recordings were transcribed. The effect of the robotics programs on students’ design process were inquired during the analysis. Initially a coding scheme developed based on the literature was used and as analysis progressed emerging new codes and themes were added according to the triangulation of data. Data was used to support each other, and analyses were conducted in an integrated manner rather than focusing on each data source (interviews, students’ drawing and video recordings) separately. An external expert was consulted to assure objectivity during the initial phases of coding and upon agreement on the coding scheme independent analysis were conducted by the researchers while corresponding with each other.

3. RESULTS

3.1. Research Question 1

Students’ scores on the TTCT were analyzed using descriptive analysis (Table 1) to determine the effects of the robotics program. Participants scored a minimum of 5, a maximum of 17.8, and an average of 9.35 on the pre-test. The post-test scores of the participants were minimum 7.2, maximum 18.4 and mean was 12.45 points. An increase in mean scores was observed upon the completion of robotics education.

Table 1.
TTCT Pre-test and Post-test Scores

TTCT scores	N	Minimum	Maximum	Mean	S.D.
Pre-test	8	5	17,8	9,35	4,81
Post-test	8	7,2	18,4	12,45	4,21

Same analysis was also conducted for the subscale scores; originality, fluency, elaboration, abstractness of title, resistance to premature closure (Table 2). When the pre-test and post-test scores of the subscales of TTCT are evaluated, an increase is observed in the scores for subscales fluency, originality and elaboration subscales. And a decrease for subscales abstractness of title and resistance to premature closure was observed in post-test scores.

Table 2.
TTCT Subscales Pre-test and Post-test Scores

TTCT Subscales	Pre-Post Test	N	Minimum	Maximum	Mean	SD
Fluency	Pre-test	8	10	35	16,88	11,22
	Post-test	8	15	46	33,63	13,76
Originality	Pre-test	8	2	23	11,50	7,11
	Post-test	8	8	21	13,63	4,72
Elaboration	Pre-test	8	7	16	11,63	2,67
	Post-test	8	8	17	12,63	3,20
Abstractness of title	Pre-test	8	1	20	5,00	6,19
	Post-test	8	0	8	3,88	3,27
Resistance to premature closure	Pre-test	8	0	9	1,75	3,01
	Post-test	8	0	2	0,50	0,76

Participants' TTCT total and subscale scores on pre- and post-test were analyzed using Wilcoxon Signed Rank Test to determine the effects of the robotics program. Wilcoxon signed rank test showed that students' total creativity scores were statistically significantly higher after completing the educational robotics training process than before completion (p=0.018) (Table 3).

Table 3.
TTCT Total and Subscale Pre-test and Post-test Scores, Wilcoxon Signed Rank Test

Posttest-Pretest	N	Z	p
Total mean	8	-2,366	0,018
Fluency	8	-2,524	0,012
Originality	8	-1,053	0,292
Elaboration	8	-0,946	0,344
Abstractness of title	8	0,075	0,733
Resistance to Premature closure	8	-0,921	0,357

In addition to the overall TTCT scores, subscale scores were also analyzed to investigate the educational robotics program's effect on the creative thinking skills of the participants (Table 3). Analysis revealed that there was a statistically significant difference between the fluency pre-test and post-test mean ranks (p=0.012). It was also concluded that there was no statistically significant difference between pre- and post-scores of the subscales of originality, elaboration, abstractness of titles and resistance to early closure between pretest and posttest rank averages (p>0.05).

3.2. Research Question 2

Students' TTCT total and subscale scores were examined to identify if there is any difference based on gender. Before and after the program, the scores received by male and female students from TYDT were examined depending on gender, and the descriptive statistics of these scores are presented in Table 4 as minimum, maximum, average and standard deviation. It is given in Table 4.

Table 4.
Descriptive Statistics for Pre- and Post-Test Scores by Gender

Gender	Male (n=4)					Female (n=4)				
Average	Min-Max	Average	SD	Skewness	Kurtosis	Min-Max	Average	SD	Skewness	Kurtosis
Pre-test	5-17,8	11,60	6,00	-0.104	-3.939	5,6-10,2	7,10	2,09	1.839	3.530
Post-test	12,6-18,4	15,90	2,64	-0.587	-1.988	7,2-10,6	9,00	1,66	-0.148	-4.608

Analysis using the Mann-Whitney U Test, shown in Table 6, revealed that there was no statistically significant difference based on gender for the grand total scores and sub-dimensions.

Table 5.
Mann-Whitney U Test Results for TTCT Overall Average and Subscales

	TCTT Overall Average	Fluency	Originality	Enrichment	Abstractness of Titles	Resistance to Premature Closure
Mann Whitney U	4.000	6.000	7.500	2.000	4.000	7.500
Z	-1.155	-0.581	-0.145	-1.753	-1.162	-0.154
p	0.248	0.561	0.885	0.080	0. 245	0.878

3.3. Research Question 3

The third research question was investigated through the comparative analysis of student's drawing, interviews and video recordings collected before and after the robotics program. The analyses were conducted with the consideration of following themes, students' perception of robots, characteristics of robots, functions of robots and algorithmic thinking skills.

Students' perception of robots was inquired with the analysis of drawings as well as interview data. Initially students identified robots mainly with codes such as toys, TV characters, technology and machines used in daily chores and their drawings of robots had more human-like features. Upon completion of the robotics program most students emphasized robots as machines that are used to solve daily life problems. Human needs and their own needs were found to be the main rationale in their explanations and design features. Their drawings were found to have more machine-like features in comparison to the initial drawing of robots (Figure 1). Some of the students' comments explaining their robot drawings were as follows.

> *"It can help with anything; you push this button, and it can do all the work"* (S1)
> "*I made a robot dog. I tell it to sit, and it sits, and I tell it up and it stands. For example, somebody has allergies to dog hair, and they may want to have a dog". (S8)*

As seen from the students' comments they were taking their own needs as well as others into consideration as they were designing their robots upon completion of the robotics program. The changes identified in drawings were found to be aligned with the content of the program.

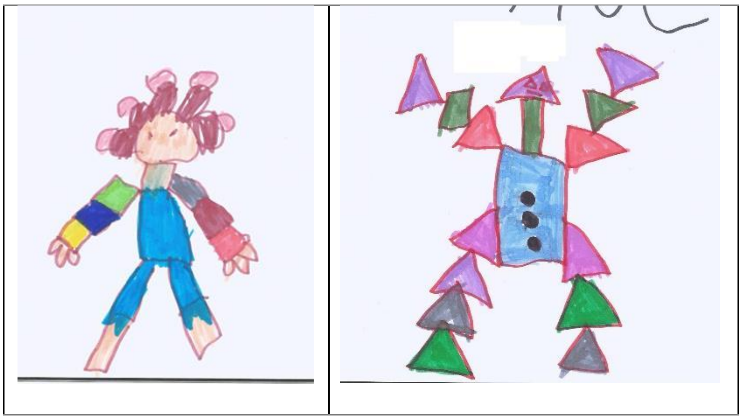

Figure 1: Student's pre- and post-program drawing of a robot

Students were then asked to design a robot. The task was identified based on a story included in the program and students were asked to help the characters in the story by designing their robots with lights. While designing their robots, students asked for paper and pen without a prompt coming from the instructor. They first drew their designs on paper and then moved to the construction phase. This was an interesting finding of the robotics program since the program did not include specific instructions on planning and drawing a draft on paper as the initial step of the design process; however, the characters of the story used planning before moving on to the construction phase.

Students were then asked to redesign the robot they were using in the classroom using LEGO pieces. They were asked to work in groups and per their choice students grouped in two as girls and boys. Robots designed by the girls were more focused on meeting a need (a moving restaurant) and the boys' robot was focusing on movement (a crocodile robot that can go fast). Girls' robot included features such as sitting areas, balcony, beds to rest and even utensils on the tables which would allow them to go anywhere while eating. Boys' robot included anatomical features such as mouth, eyes, tail. Some of their explanations of their robots were as follows.

> "*That's a balcony so that people can get air" (S3).*
> *"We added additional tires and eyes and a long tail so that our crocodile can go faster" (K6).*

As a part of this task students were also asked to identify characteristics of a robot. Initial students' comments mostly focused on mechanical/ hardware features of robots. Identified codes included tire, engine, mechanical hands, energy, music player, and dryer. There were no statements identifying software of a robot in the pre-program data. Upon completion of the program in addition to the identified codes in pre-program data, students made comments on software, algorithmic statements, using solar panels for energy and using coding blocks to move the robot. Later they were talking about hardware, software, and movement. They also identified humans as the controller of robots and on and off switches to control robots after completing the program. Students presented a solid understanding of the relationship between software and hardware.

> "*We need to write a code for it to move. We also need to code the horn so that it honks" (K4)*

In their thinking process and designs students included elements of coding blocks and showed algorithmic thinking. While explaining what kind of software a robot needs to move students used statements indicating algorithmic thinking in terms of the robot making a sound, moving or drying itself. They were able to make the connections between the concepts of coding blocks, pattern, hardware, software and how they are related to the movement of the robot. While the robot was performing a task following a square path students discovered the loops and responded "there is a pattern here" when placing the coding blocks. The patterns students noticed consist of shapes and numbers in a certain order and sequence, and students learned the concept of pattern in other courses. They were able to connect previous knowledge with what they were learning in the robotics program. Additionally, students were able to use the following skills: making predictions, grouping, comparison, establishing cause-effect relationships, problem solving, observation, and creating patterns during robotics education.

4. CONCLUSIONS

Human necessities are one of the driving forces in technological advancements including robotics. Following industrialization robots were machines that were put in work to protect humans from harm's way. Today, robots and robotics sciences are in every aspect of social life to meet our needs (Garcia et al, 2007). The barriers between disciplines are fading and we are seeing robotics sciences' products such as three-dimensional printers being used in printing organs or microchips being implemented in humans. A holistic approach is very much needed in education to create the bridge between disciplines and STEM education to be able to prepare youth for the future.

Educational robotics and STEM education are considered powerful teaching approaches that are suitable for all age groups. Integration of educational robotics into teaching creates a prospect for students to gain knowledge and develop necessary skills such as creative thinking. With all these premises in mind, this study focused on the development of a robotics program for early childhood education and testing its effects on students' creativity as well as students' understanding of robots. Findings of this study show a positive impact of the program on students' creative thinking skills. Students' TTCT total scores were increased after the robotics education program as well as the fluency scores though no gender differences were found. Fluency is the ability to produce different ideas and Torrance (1977) states that an individual with fluent thinking skills produces different ideas through drawings or ordinary objects, arranges blocks and other game materials in various ways, easily assembles and reassembles complex machines, draws sketches in his mind, and arranges objects and materials in space. During the robotics education program students were asked to design robots, come up with new ideas, use regular materials to design new objects and use mechanical components. We believe these are the features contributed to the positive outcome in fluency scores. Through the robotics program students were able to study different aspects of robots' functions as well as coding and patterns. Positive effect of robotics education was shown in literature as well (Atmatzidou ve Demetriadis, 2016; Berg ve Eisenberg, 2000; Bers vd., 2006; Beynon, 2016; Catlin, 2016; Danahy vd., 2013; Resnick, Sullivan, Kazakoff ve Bers, 2013) which was also supported during this study.

Students' understanding of robots was also changed after completion of the robotics program. Their perception of robots was relying on TV and robots were machines and toys. Upon completion of the program students developed a better understanding of robots and how they function. As students stated, "robots help us during our daily life and help us to solve problems". Human need was an important element of their understanding which was observed in their drawings and designs as well. The robotics education program provided students with opportunities to use different skills including making predictions, grouping, comparison, establish cause effect relationships, problem solving, observation, and create patterns, which allowed them to develop an understanding of relationships between the concepts, hardware, software and coding and exhibited algorithmic thinking skills. Evripidou et al (2021) also reports positive outcome of a program using tangibles in terms of increasing students' algorithmic thinking skills. Developing an understanding of the foundational concepts of robots and robotics, along with acquiring the requisite skills, is crucial for preparing future generations. Early childhood education holds significant promise in this regard. Research in early childhood education highlights positive outcomes from integrating educational robotics such as demonstrating improvements in algorithmic thinking and the ability of students to plan, code and execute fundamental rules for robot manipulation (Elkin, Sullivan, & Bers, 2016; Janka, 2008; Mioduser & Levy, 2010; Sullivan, Kazakoff, & Bers, 2013). This study also shows that students in early childhood education are successfully able to complete tasks of programming and coding robots with age appropriately designed interfaces and educational toys.

The learning environment created with the robotics program was hands-on, motivating and allowed collaboration among students. Collaborative learning environments are reported to nurture students' interpersonal skills (de Vries & Mottier, 2006; Chin, Hong, Chen, 2014). Robotics education is also reported to support problem solving and critical thinking skills in other studies (Atmatzidou, Demetriadis, Nika, 2018; de Vries & Mottier, 2006; Toumi et al, 2018). Creativity is a skill that can be learned. Using educational programs, such as the robotics program used in this research, allows students to practice, develop and master skills that will be necessary in their adult lives. Considering the rapid changes and developments we experience in life we are only able to make predictions for the future. Although we may be uncertain regarding many aspects of the future, we can be sure that it will be competitive, economically and socially. Therefore, developing a strong foundation of knowledge and skills in youth is a necessity. Creative thinking skills affect not only the workforce, but also the individual's perspective on life and is one of the skills that most deeply affects the self-realization process. For this reason, implementation of programs supporting the development and practice of skills such as creative thinking, algorithmic thinking, problem solving, collaboration and reading plays a significant role in students' development.

5. LIMITATIONS AND FUTURE RESEARCH NEEDS

STEM is an important approach in the field of education as it integrates disciplines which are presented separately in the traditional approach. As revealed in the study, the STEM paradigm has an important potential to develop students' creative thinking skills. For this reason, the necessary importance should be given to what kind of approaches can be used in educational processes, starting from the pre-school period, which is the most critical stage in the life of the individual. It is of great importance that the STEM approach becomes widespread in every school type. STEM education is not and should not be limited to STEM disciplines and professional development opportunities should include both STEM and non-STEM teachers regardless of the grade level they teach.

The results of the study are limited to a small group of preschool students and cannot be generalized. However, considering other studies presenting positive effects of robotics education and STEM programs, future research is needed on the topic. Different school settings, different age groups and different components of robotics programs can be researched. Such studies not only contribute to educational research with the results they present but also with the educational materials they develop. Another aspect of research can be the design of learning environments which was not a focus in the study.

The findings of this study showed no statistically significant difference for originality, enrichment, abstractness of the titles and resistance to premature closure subscales of TTCT. This outcome may be due to the small number of participants. The implementation of the program with larger participant groups will ensure that the robotics program's effects can be determined more clearly. Another limitation of the study was participants' socio-economic status. Investigating the effects of the robotics program with students from different socio-economic groups would shed a better light on the effects of the program.

Research and Publication Ethics Statement

This study is based on the first author's master's degree thesis. This study was ethically approved by the Hacettepe University Ethics Committee with its decision dated 06.06.2017 and numbered 35853172/431-2220.

Contribution Rates of Authors to the Article

The authors declare that they have contributed equally to the article.

Statement of Interest

The authors declare that there is no conflict of interest between them.

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