How to Enhance Creativity and Inquiry-Based Science Education in Early Childhood-Robotic Moon Settlement Project

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Abstract

In this novel empirical study, the authors investigate how creative are our children and how robotics education final projects can promote creative thinking and engage children in science, engineering, and technology topics. This study is based on a unique Early Age Robotics (EAR) program running since 2016 for over 2000 children. A final project, related to use of robots in Moon settlements, is used to motivate children to be creative and to promote inquiry-based science education. Using a mixed-method study, we analyzed interviews and projects of 46 children (aged 5 - 7) who studied technology and robotics as a compulsory component of their curriculum. In addition, posters created by first graders were analyses by judges to establish diversity and originality of the solutions. Children's explanations of the need, the technological challenge and the solution are analyzed. Child's feelings about himself, his team and others' creativity are investigated. The results show that most of the children are very creative, value their teams and their creativity. Also encouraging is the gender equality found in this technological area. The findings show that after careful decision process, when given the same problem, children successfully identified different needs and challenges and created numerous solutions. Interviews show that most of the children understood what the need of the project was, what the challenge was and what they created. These significant results should be considered by EAR stakeholders to motivate children to be original, to promote creative thinking and science education in early childhood.

Keywords

Robotics in Education (RE), 21st Century Skills, Creative Thinking, Innovation, Constructivism, Inquiry-Based Science Education (IBSE)

1. Introduction

Creativity is one of the 21st century essential skills. Some people think that creativity is a natural talent or a trait that you either have or have not. Today we know that creativity is not a natural ability and can be taught. That is why creative thinking and innovation became one of the goals in modern educational institutions. The question "how to enhance creativity" has been subject of research and discussion for decades. Creativity requires a learning environment that fosters originality and thinks out of the box. Creativity is sometimes associated with arts and more specifically music. However, creative thinking is important and required in every field. In this study we claim that robotics can be used to motivate children to be original, to promote creative thinking and inquiry-based science education.

One of the fields that can enhance creativity and science education is robotics. Robotics in education (RE) and Early Age Robotics (EAR) are perceived by children as a fun activity and as an exciting learning environment (Sullivan, 2008; Rusk et al., 2008; Eck et al., 2014; Eguchi, 2014; Zviel-Girshin, & Rosenberg, 2018; Bers, González-González, & Armas-Torres, 2019; Zviel-Girshin, Luria, & Shaham, 2020). If done correctly, RE motivates children to think, create and explore. Using robotics in education can improve children's attitudes toward technology and science education (Cejka, Rogers, & Portsmore, 2006; Benitti, 2012; McLemore & Wehry, 2016; Sharma, Papavlasopoulou, & Giannakos, 2019). Educational robotics is an effective learning tool for promoting and encouraging students' science, technology, engineering, and mathematics (STEM) learning. One of the main benefits of educational robotics is its potential to inspire curiosity and creativity in students. In addition, educational robotics gives students the opportunity to find ways to work together, foster collaboration skills, express themselves using technological tools, think critically and innovatively (Eguchi & Uribe, 2017; Noh & Lee, 2020). Children who participate in RE programs are required to explore and think creatively in order to reach a solution (Bers, Seddighin, & Sullivan, 2013).

There is no doubt that creativity is the most important human resource of all, a valued component of modern enterprises and organizations. Without creativity, there would be no progress, and we would be forever repeating the same patterns (De Bono, 1995). In our desire to educate and prepare our children for the future, we can assume that rapid advances in technology and automation will continue. Many customer-facing jobs will be replaced by machines, bots or go online, majority of routine-intensive, so called "boring", human jobs will disappear. Originality and thinking out of the box will be highly valued and demanded by industry and life. And since creativity skills can be learned (Mellou, 1996; Lindström, 2006; Treffinger, Isaksen, & Stead-Dorval, 2006; Trilling & Fadel, 2009; Hernández-Torrano & Ibrayeva, 2020; Lunevich, 2021) it is important to enhance creative thinking in early childhood.

A longitude study by George Land, who used NASA imaginative thinking test to examine the creativity of 1600 children, revealed that we are all born naturally creative and as we grow up to be adults, we learn to be uncreative (Land & Jarman, 1992). From 98% of children who were considered creative geniuses at the age of 5 to only 30% by grade school (age 10) and only 2% of adults. Land concludes that non-creative behaviour is learned. According to this argument, at schools too much emphasis is placed on answer being wrong or right, leaving too little room for the fuzzy numerous intermediate solutions due to creativity.

Only in 20th century compulsory school attendance become the norm in most countries. From the time of Napoleon to that of Bismarck, this policy was quickly adopted and adapted by governments that needed better workers and soldiers. Historically our traditional school system was designed during the industrial revolution over 200 years ago, to train for industrial behaviour and skills, to be good workers and to follow instructions, to be wrong or right, but not to be creative and innovative. In many cases this type of thinking and working is still promoted in many educational settings. Sir Ken Robinson states that the very future of our civilization hinges upon the creative capabilities of young people and that one of the most important things we can do in schools is foster creativity (Robinson, 2017). This shift from standardised thinking and testing, from being wrong or right towards being imaginative and creative can be done through robotics education, in which majority of task and solutions require creative thinking and innovation. Most importantly, RE allows all students to develop different solutions to the same problem and encourages innovation and creativity.

Adding creativity and innovation topics to well-defined heavily loaded programs and courses can be difficult or even impossible to implement. However, the right mix of creativity along with well-defined curriculum can help students to be innovative and encourage them to learn and try new things. Therefore, one of the appropriate educational settings for learning creativity is the field of robotics (Alimisis, 2013; Danahy et al., 2014; Bers et al., 2014; Di Lieto et al., 2017; Bers, González-González, & Armas-Torres, 2019). Creative potential of students can be either supported or suppressed by learning environment. During robotic activities creativity is enhanced by encouraging each participant to apply creative thinking, imagine and implementing new solutions and ideas to some new robotic models. By its nature creativity in RE is associated with the constructionist learning paradigm and the processes of building, programming and manipulating of new robotic models.

RE, if done correctly, also promotes inquiry-based science education (IBSE). It allows inspiring way of learning science by designing and conducting their own scientific investigations and discovering problems that can be solved with help of robots. This stimulates engaging and active learning (Braund & Driver, 2005; Rocard et al., 2007).

In this paper, the authors present findings regarding the use of robotics and technology education in kindergarten and early elementary school as a process for the enhancement of science and technology education, and for the development of essential 21st century skills of creativity and creative thinking. Researchers claim that the correct choice of final problem provides an educational setting that stimulates originality, innovation, creative thinking and imaginative thought. This final problem also stimulates inquiry-based science education and teamwork. In this novel empirical study, the authors investigate how creative are our children, how robotics education inquiry-based final problem can promote creative thinking and engage children in scientific research related to usage of robots in Moon settlements. Researchers also investigate child's understanding of what was the challenge that their team tried to solve, are there gender or age-related differences in children's understanding. As well, participant's feeling towards their own creativity, their team members creative ideas and originality of other projects are examined.

The rest of the paper is structured as follows. First a program description is given. Later research methodology, questions and experiment are introduced. Then results and discussions section for this study are described. Finally, conclusion of this study is presented.

2. Program Description

2.1. Basic Information about the Program

In 2016 the authors started a novel robotics education program, called 'Robotics as a springboard to enhance technological thinking and learning values in early childhood', started in Israel. The program started with 4 kindergartens and 12 first grade classes from various socio-economic and ethnic backgrounds. Later it was extended to 5 kindergartens and 20 first grade classes in 6 different schools.

The aim of the program is to foster the integration of robotics as a part of science and technology education in a playful way, to give each child the best start possible and to help the child to acquire essential 21st century skills. This is a unique program in which general education teachers and kindergarten teachers play an important role of robotics instructors. They are trained and serve as robotics instructors (with the assistance and support of program managers). This allows the instructor to be very knowledgeable about their students and have special relations with them. In this program kindergarteners and first graders study technology and robotics as a compulsory component of the curriculum. The program is funded in part by private donations, and partly by regional council. Private donations were needed to implement principles of economic and gender equality, since parents were not required to pay any fees for participation in the program. Robotics lessons became part of the compulsory, core programs of the kindergartens and elementary schools participating in the program. This program was approved by Israeli Ministry of Education and a special official certification to conduct the research was received from the Head Science Officer of Israeli Ministry of Education.

The program has several different goals that can be accomplished via robotics education. The list of these goals includes increasing children's confidence in using technology, enhancement of technology and science education, preparation of children for the realities of our technology rich and omnipresent world. Increasing child's self-confidence and self-efficacy, and belief in their own personal capabilities (Zviel-Girshin, Luria, & Shaham, 2020). Additional goals are acquiring essential 21st century skills like collaborative problem-solving, teamwork, communication, creativity and imagination, critical thinking and problem solving (Dede, 2010; Binkley et al., 2010).

One of the principles of this program is to provide a variety of learning opportunities and experiences for each child regardless of his/her gender, economic status, and cultural background. Additional principle of the program was to use the teacher that children are accustomed to, their personal familiar caregiver, and not a stranger as robotics instructor. These are local, "every day" general education teachers that were supported and so were able to teach the required content.

2.2. Program Description in Kindergartens

In the kindergartens a special robotics lesson was added once a week to the kindergarten curriculum. LEGO Education WeDo kit was the main equipment. This kit comes with specially designed easy-to-use programming environment that can be installed on desktop and tablet. A dedicated 'robotics area' was created in each kindergarten. It included tables, variety of electronic and robotics kits, tablets and computers in which LEGO Education programming environment was installed.

A local kindergarten teacher taught different robotics and technology related topics following a curriculum designed and tested beforehand. Each teacher underwent a training before and during the school year. A different kindergarten teacher, called "expert", joined the local teacher. This additional expert visited each kindergarten once a week for an hour or two to help the local teacher with robotics education, to build or improve its confidence in the subject. At the beginning of the program the role of this expert was to reinforce the local instructor, but later the presence of the expert allowed division of the children into smaller groups and added a personal touch to each lesson, allowed creation and processing ideas and forging deeper understanding of the learning subject. Working in smaller groups (groups of 2 - 4 children) allowed each teacher to stimulate the child's natural curiosity by asking questions and encouraging each group member to think, provide different solutions and explain these solutions (Schweingruber, Duschl, & Shouse, 2007; National Research Council, 2007). It also allowed practicing oral communication and usage of the correct terms related to the discussed subjects. In addition, during each meeting, several groups of 2 - 4 children received special, individualised training in which they were asked to perform some extra activities, to give an oral explanation of their choices, to predict outcomes of some of their decisions or solutions. This playful discussion allowed children to think innovatively, to find and discuss some original or alternative solutions, to cooperate and collaborate, to prove that their solution is a correct one and to provide a friendly learning community.

2.3. Program Description in Elementary Schools

In elementary schools, a two-hour robotics lesson was added to the first-grade curriculum. The main equipment in this case was LEGO Education WeDo 2.0, a kit specially designed for elementary schools, and accompanying materials that included an eLearning program, that helped teachers master the WeDo 2.0 Core Set and WeDo 2.0 Curriculum Pack that covered life, physical, earth, and space sciences, as well as engineering. Other kits, like KNEX, Snap Circuit, regular LEGO construction kits and others construction kits were similarly used.

Homeroom general education teacher taught the robotics class. Each lesson lasted for two academic hours per week. During the lesson the class was divided into two groups, every other week one group stayed in a regular classroom with the regular teacher and the other went to a science classroom, where a science teacher, that completed training in the field of robotics, helped the children to perform a robotic activity or to solve a problem in the field of robotics and technology. Each half of the class was later divided into smaller teams (2 - 4 members) to work together on collaborative problem-solving assignments. Each half of the class employed a mediated learning approach that included both direct instruction and open-ended, student directed inquiry. Since creativity begins with a foundation of knowledge, learning a discipline, and mastering a way of thinking, directed instruction allowed each student to get basic knowledge of the discipline and open-ended instruction allowed collaboration, designing and discussing different solutions and mastering a way of thinking. Direct instruction included short lectures and/or multimedia demonstration of the learning concept, principle, model, problem or activity. Open-ended, student-directed inquiry consisted of students working in teams to solve problems posed as programming and design challenges. Students were encouraged to give oral explanation of their choices, to predict outcomes of some of their decisions or solutions. Some of the challenges were very well-defined and some were intentionally loosely defined, leaving room for creativity and imagination.

Some of the tasks were designed to promote inquiry-based science education. These tasks were usually divided into two-three weeks activities, where some scientific question was raised during the first week and students were asked several questions or problems to think about or to find some possible solution or a way of solving it, later students presented those idea and solutions and were asked to think how those solutions, ideas or techniques can be used in robotics.

2.4. An Importance of Final Challenge

During years of our program several approaches related to a final challenge and its presentation were tested. Among the approaches were:

- no final project at all, only teaching the syllabus;
- a final challenge that was presented at kindergarten or school class only;
- a final project that was presented at kindergarten and the whole school at the school's annual exhibition;
- final project models, along with descriptive posters, were presented at kindergartens and school's annual exhibition and afterwards, all participating schools were invited to some kind of culmination event, usually called a "Robotics Day", where they presented their work to other children, teachers, family members, and local authorities.

Several of the approaches were tested during the first year of the program and others were tested later. Adding a final project to the program was found as a best approach for promoting robotics and inquiry-based science education.

Every year a final project had a specific theme, for example, how robots can help humans at the Moon or how robots can be used to help domestic and wild animals or how robots or robotic devices can be used in a child's room. To increase the attractiveness and learning profits of those final projects they were organized like exhibition and not like a competition (Rusk et al., 2008).

The Moon Settlement problem was chosen after careful decision process, aiming for the most motivation challenge. In 2018 the "Beresheet" (Genesis) project to send a small spacecraft lander to the moon was launched. Genesis was a small robotic lunar lander and lunar probe operated by SpaceIL and Israel Aerospace Industries. One of the aims of this project was inspiring youth and promoting careers in STEM therefore SpaceIL created a lot of educational materials and booklets explaining lunar lander concepts, lander structure, its launch, planned landing site and operations and more. Genesis project was interleaved into school programs and discussed at schools and kindergartens during entire school year at different classes. That is why the topic of Moon settlement was chosen as a final challenge for the robotics projects at kindergartens and first grade. The definition of the project was "the challenges after we land on the Moon".

3. Research Methodology, Participants, Experiment and Questions

3.1. Methodology

Case study methodology can be used with both the qualitative approach and quantitative approach. Data was collected using a mixed-methods approach, incorporating aspects of qualitative and quantitative analysis methods (Creswell, 2014). In the qualitative educational approach open content interviews with children were conducted. Different questions about the program, robotic models, child's feeling, teamwork and creativity were asked. Qualitative analysis also included in-depth examination of posters, models, audio and video recordings and analysis of their transcription. In the quantitative part a survey was distributed. Each child answered the questions with the help of a research assistant.

The first part of the questionnaire comprised questions related to personal information of the participants. In the second part some of the questions were open-ended and some were expression of the agreement with statements on a Likert scale of 1 to 5.

A special multidisciplinary team of experts examined the program. Different team members looked at different aspects of the program: educational, linguistic, scientific, engineering, managerial, psychological and more. Specially designed surveys, interviews and activities were conducted by the team members. Later additional team of judges, who were experts in the fields of robotics, science education and early childhood education were asked to measure creativity, innovation and originality of projects.

Data was collected in the form of a survey that each child answered with the help of a research assistant (because many of the participants did not know how to read or write sufficiently to answer a questionnaire). A research assistant recorded answers to open-ended questions, read the close-ended questions and possible answers to the children, and after the child gave the answer, the assistant marked the child's selection.

3.2. Participants

Over 400 children of the ages 4 to 7 took part at this project, 4 kindergartens and 3 schools with 12 first grade classes. Teams of 4 - 6 children were formed for solving and presenting the final project. All together 15 kindergarten and 51 first grade projects were submitted for participation in the Robotics Day event. Performance assessments, such as divergent thinking tests, have been criticized as too narrow to assess children's engagement in creative processes, while child or parent ratings are considered very subjective (Beghetto, Kaufman, & Baxter, 2011). Therefore, ratings by a divergent group of teachers or experts are generally considered a more reliable form of measurement (Kaufman & Baer, 2012). In our study judges, who were experts in the fields of robotics, science education and early childhood education were asked to analyze and rate the diversity of the 21 first grade projects and posters. Analysis of posters, identifying the need, problem and the solution and the originality of the solution is presented is the results section. Kindergarten's posters were not analyzed because the children at this age can't write, and the posters were prepared by a kindergarten teacher. Also, at each kindergarten the format of the poster was different.

In addition to the analysis of posters and robots the summary of the one-to-one interviews with 31 randomly selected first grade team members and 15 kindergarteners are presented here. Children volunteered to talk to the researchers or were randomly selected by the project manager. Children presented their robotic models, explained what the model does, how it works and answered the researcher's questions. Each child was asked the same list of questions (with minor adaptation to school and kindergarten). The questions were asked by the same research assistant and all the answers were recorded and transcribed later.

3.3. Experiment

At the end of the school year all teams received some general task, final project that they were supposed to solve with the help of robots. Children worked in teams of 4 - 6 children. These final projects, both the model and the poster, were presented at the exhibition of the projects at each of the schools. Later all schools which participated in the program were invited to a hackathon, the "Robotics Day" activity at Science Centre where they presented their work to other children, teachers, family members and local authorities.

The participants were asked to identify a need and a challenge for human astronauts or settlers on the Moon, to analyze this challenge from scientific point of view (environmental or technological), to construct and program a creative solution for this need and challenge using robots. The evaluation of final projects had several aspects, including research into the subject area of the year's tasks, identifying the need, the problem and the solution, robot's design, poster, and oral presentation. Analysis of projects, teams and teamwork, participant's explanations of needs, challenges, solutions are presented. Diversity of the ideas and originality of the solutions were examined by judges.

3.4. Research Questions

In this study the research questions were as follows:

RQ1. How diverse were the problems and how original were the solutions? How many different and original projects were created for the same problem?

RQ2. Do children understand what they created? What was the challenge? Are there gender or age-related differences in children's understanding?

RQ3. How creative the children feel?

To answer these questions a team of experts in the fields of robotics, science education and early childhood education was asked to measure creativity, diversity and originality of different projects. The judges measured variety of ideas (flexibility), uniqueness of the project (originality) and elaboration (details of ideas).

A research assistant conducted one on one interviews with team members and asked them several questions about the project, the idea they had and its implementation, their feeling towards their own creativity, their team members creative ideas and originality of other projects. An analysis of questionnaires administered to the children was done using IBM SPSS Statistics 27 software.

4. Results and Discussion

4.1. Diversity of Different Moon Projects

Usually when given the same problem children tend to give the same solution but RE allows participants to develop different solutions for the same problem. To answer the first research question, about diversity of the problems and originality of the solutions, a group of experts was asked to measure diversity and originality of different Moon projects posters (**Figure 1**). Only first grade posters were chosen for this part of the experiment, since kindergarten children at this age can't write and their posters were prepared by a kindergarten teacher or an assistant.

At first grade all the posters had the same structure. All together 21 randomly selected first grade team's posters were analyzed by judges. The structure of the poster was:

- a general information part which included the following items: a name of the project, a name of school/class, a list of team members,
- relevant for the project facts about the Moon,
- what is the need? what is the technological challenge?
- a robotic model description and its picture (including some technical information: how many sensors and which sensors were used, a code example, usage of motors, some interesting building elements).

An example of one of the posters:

- An ice crasher, first grade school name and a list of 5 team members.
- Moon has no water, no food, no air, no atmosphere. Day and night are two weeks. The traces remain on the surface.
- The need: obtain water for the people of the colony on the Moon. The challenge: how do we get water for the people of the colony?
- The robot rotates to crush the ice and then the astronaut can drink water. The robot has a motion sensor, a motor which is used for the rotation of the poll with the arm, and a code snapshot example.

Judges were asked to analyze an inquiry-based science education (IBSE) part of the poster:

- relevant for the project facts about the Moon.
- what is the need? what is the technological challenge?
- the proposed solution and its originality.

The originality of the solution was measured using the following principles: how different the designed model was from one of the educational WeDo models (4 points max), usage of interesting and novel building elements (3 points max), uniqueness of the project and its difference from other proposed projects (3 points max). The originality was measured as a grade between 1 - 10. In this part of the experiment judges worked together and made common decisions.

Figure 1. Examples of posters and models.

The analysis of the results revealed that children mentioned in their posters the following relevant for the problem facts about the Moon: an existence of ice or glacier (9 times) 42.8%, meteors or meteorites (8 times) 38.1%, an existence of craters (8 times) 38.1%, does not have an atmosphere (7 times) 33.4%, no air (4 times) 19.0%, no oxygen (3 times) 14.3%, no water (6 times) 28.6%, a hot day and a cold night (5 times) 23.8%, Moon has much less gravity than Earth (3 times) 14.3%, day and night are two weeks, no houses, no fuel, the Moon revolves around the sun, the earth and itself, no wind, the traces remain (1 time) 4.8%.

The detailed analysis of the need and technological challenge showed that some of the teams identified the same need. However, majority of the solutions were very different. The variety of the project impressed the judges: from obtaining water, protection from meteors to building houses or using a conveyor belt that to avoid the craters. The diversity of needs, challenges and marks for the originality of the solution are shown in "Table 1". All the needs and the challenges are copied from posters without fixing any mistakes, misconceptions about feasibility of the idea or incorrect usage of the terms.

The median grade for originality was 9, ranging between 7 - 10, the average grade was 8.67 (SD = 0.91). 9 groups of projects were defined according to the need. The largest group, having 5 projects in it, was an "obtaining water" problem. This group had the average originality grade of 9.2 which means that even in this group of the same need the proposed solutions were very different. The next group ("need oxygen to live") had 4 different projects with the average originality grade of 9. A "protect people from meteors" group had 3 different projects in it with the average originality grade of 8.33, since some similarity was found between the solutions. An "avoid craters" group also had 3 projects and the average originality grade of 8.33, but in this group the reason for loosing points was similarity to the existing WeDo models. A group of "there are no houses on the Moon" had 2 projects, with a doubtable feasibility of the solution, and had the average originality grade of 8. 4. A single projects group increased a number of unique ideas.

All the children were given the same problem however children managed to create different solutions to the same problem. The results show that projects were very diverse, and the solutions were very original. Flexibility, elaboration and originality of the projects were very high. Even in the same group the originality of the proposed solutions was very high.

4.2. Children's Understanding of the Problem and the Solution

To answer the second and third research questions one-to-one interviews with 46 children were analyzed. There were 31 first grade students and 15 kindergarteners (67% vs. 33%). The proportion of boys in the sample was slightly higher than girls 24 boys and 22 girls (52% vs. 48%). During the interview each child had a robotic model with him (but not a poster). Children presented their robotic models,

Table 1. Examples of different needs, technological challenges and originality of the solutions.

The need	The technological challenge	The originality of the solution (1 - 10)
Obtain water for the people of the colony on the moon (5 projects)	How can you dig in the ground and get to the ice?	9
	There is ice under the Moon so we decided to carve and find water.	10
	Where would we put the ice and how will we melt the ice?	10
	How to carve and find water?	8
	How to search and dig for the water on the Moon that the astronauts can drink?	9
Need oxygen to live (4 projects)	How will we supply oxygen to the people of the colony in their home?	8
	How to bring oxygen to the Moon?	9
	How to provide oxygen to the people of the colony so that they can move around freely in the house without the need for oxygen masks?	10
	How to bring air to astronauts in the middle of a mission?	9
Protect the people of the colony from meteors (3 projects)	How to protect the astronauts from meteors?	8
	How to protect the people of the colony from meteors?	9
	How to throw the meteorite out of orbit and prevent the meteorite from hitting the moon?	8
Avoid craters on the Moon so that the spacecraft can travel easily on the Moon, explore places (3 projects)	How to build a car that safely transports things to the spacecraft?	10
	How to drive without falling into craters?	7
	How can we move from place to place in the Moon without falling in craters?	8
There are no houses on the Moon (2 projects)	How to help people who are on the Moon to sleep there?	8
	How to build houses on the Moon?	8
Equipment of the colonist can be damaged	How to bring a new equipment (helmet) instead of the damaged one?	7
The goal was to save people in space. There is no solution in space for people's injuries	How to lift an injured person and bring to the space station/hospital?	9
Cars were not allowed to refuel in space	When the fuel runs out in space, how it will be possible to fill the fuel in space?	9
Steroids hit space, they create potholes in space and people can fall	How to flip asteroids that do not hit the Moon?	9

explained what the model does, and answered the researcher's questions. Each child was asked the same list of questions (with minor adaptation to school and kindergarten). Some of the questions were open-ended and some were expression of the agreement with statements on a Likert scale of 1 to 5.

To answer the second research questions each child was asked to explain what the robot does, how it works, for which problem the robot was designed? The answers to those open-ended questions were recorded and transcribed later. An analysis of each open-ended question in this section was done by the judge. A score for understanding was defined in a scale from 3 to 1, where 3 meaning "the child understands what was created", 2 meaning "the child partially understands what was created" and 1 meaning "the child does not understand what was created". To increase the reliability of the analysis of these transcripts, three judges read each transcript and gave it a score. The same scale was used to summarize the understanding of "what was the challenge". In case of disagreement between the judges the following procedure was defined: an additional judge will be given a transcript to analyze, in case that this judge agrees with majority, the majority decision stays and in case of disagreement a meeting of all judges should be scheduled to resolve the disagreement. In 46 cases the disagreement was only about 4 interviews, and in all this cases an additional judge agreed with majority of judges.

The results show that children do understand what was created: 87% (40) got 3 out of 3 points, 13% (6) got 2 out of 2 points. All the children understood or partially understood what was created. Our findings show that girls have a higher understanding of what was created 95.5% got 3 out of 3 points and only 79.2% of the boys got 3 points ("Table 2"). However this difference was not statistically significant. The results of Fisher's exact test indicated no relationship between gender and an understanding of what was created, as the p-value was greater than 0.05 ($p = 0.19$). Age related results show that 90.3% of school children felt that they understand what was created and only 80.0% of the children in kindergarten felt the same ("Table 3"). The results of the Fisher's exact test indicated no

Table 2. Frequency and percentage table presenting gender related data about understanding.

Question	Gender		Frequency	Percent
Does the child understand what was created?	Boys	yes (3)	19	79.2
		partially (2)	5	20.8
		no (1)	0	0
	Girls	yes (3)	21	95.5
		partially (2)	1	4.5
		no (1)	0	0
Does the child understand what the challenge was?	Boys	yes (3)	18	75.0
		partially (2)	5	20.8
		no (1)	1	4.2
	Girls	yes (3)	19	86.4
		partially (2)	1	4.5
		no (1)	2	9.1

Table 3. Frequency and percentage table presenting age related data about understanding.

Question	Age		Frequency	Percent
Does the child understand what was created?	Kindergarten	yes (3)		80.0
		partially (2)	3	20.0
		no (1)	0	0
	Grade A	yes (3)	28	90.3
		partially (2)	3	9.7
		no (1)	0	0
Does the child understand what the challenge was?	Kindergarten	yes (3)	11	73.3
		partially (2)	3	20.0
		no (1)	1	6.7
	Grade A	yes (3)	26	83.9
		partially (2)	3	9.7
		no (1)	2	6.5

relationship between child's age and judged value of an understanding of what was created ($p = 0.375$).

Analysis of the question "Does the child understand what the challenge was?" revealed that 80.4% got 3 out of 3 points, 13.0% got 2 points and only 6.5% showed no understanding of the challenge. Our findings show that girls once again have a higher understanding of what was the challenge 86.4% got 3 out of 3 points and only 75.0% of the boys got 3 points ("Table 2"), though this difference was not statistically significant. The results of Fisher's exact test indicated no relationship between gender and an understanding of the challenge, as the p-value was greater than 0.05 ($p = 0.334$). Age related results show that 83.9% of school children felt that they understand what the challenge was and only 73.3% of the children in kindergarten felt the same ("Table 3"). The results of the Fisher's exact test indicated no relationship between child's age and judged value of his/her response to the question ($p = 0.607$).

As was expected Kendall's tau-b correlation between child's understanding of what was created and child's understanding of the challenge showed a significant correlation (Kendall's tau-b = 0.589, p = 0.000). This means that all children who understood the solution (what was created) also had a better understanding of the technological challenge that this solution tried to solve.

This finding supports the claim that children in early childhood do understand what the challenge was and what they created. Girls higher understanding of the challenge and the solution can be explained by slightly higher communication and verbal development at this age. The same explanation can be used to explain the age-related differences between kindergarteners and first graders. However, in both cases the difference was not statistically significant.

4.3. Creativity Assessment

To answer the third research question several interview statements related to the feeling of creativity were analyzed. Statements could be divided into several categories: child's reflection, reflection on the whole team, feeling about creativity of others. To increase the questionnaire's reliability some of the statements were worded in a reverse manner. As the normal distribution assumption of the responses was rejected in favor of the Shapiro-Wilk test (Corder & Foreman, 2014), we could not apply parametric methods and therefore used non-parametric statistics.

Kendall's tau-b correlations between the responses were calculated. These are presented in "**Table 4**" where * means that correlation is significant at the 0.05 level ($p < 0.05$) and ** means that correlation is significant at the 0.01 level ($p < 0.01$).

Child's reflection on creativity showed that 50% (23) strongly agreed and 28.3% (13) agreed with the statement "I was the most creative team member". The results show significant correlation between this statement and "Other projects used less new elements than us", "What element you invented in this project" and a negative correlation with "Other team members were more creative than me". Majority of children reported that they've added some new element to the project: 76.1% of the children.

Huang et al. (2020) claim that male and female students (of the age 14) exhibited no significant difference in creative thinking or creative self-efficacy, defined as the belief one has the ability to produce creative outcomes. Our results are similar for the younger age.

"The project idea came from …" statement showed that 26.1% (12) reported from me, 26.1% (12) reported another team member, 48.7% (22) reported together. This finding enhances the importance of the teamwork.

Regarding most children felt that their team was very creative: 47.8% (22) strongly agreed and 34.8% (16) agreed with the statement. 58.7% (27) strongly

Table 4. Kendall's tau-b correlations between the responses to the 9 statements.

Statement	1	2	3	4	5	6	7	8	9
1. I was the most creative team member	1								
2. Our team was very creative	0.237	1							
3. Other team members were more creative than me	−0.366**	−0.182	1						
4. Other projects used less new elements than us	0.381**	−0.014	−0.083	1					
5. The project idea came from …	00.028	0.081	−0.042	−0.178	1				
6. What element you invented in this project	0.342*	0.212	−0.330*	0.034	0.024	1			
7. I feel that other teams were more creative than us	0.104	−0.219	−0.123	−0.137	0.017	−0.077	1		
8. I would be glad to change the team	0.042	−0.326*	−0.123	−0.052	0.120	−0.089	0.449**	1	
9. I will be happy to participate in this program next year	−0.002	0.039	0.007	−0.006	0.032	−0.108	0.207	−0.086	1

disagreed and 17.4% (8) disagreed with the statement "I would be glad to change the team". Only small number of children felt that other teams were more creative than us: 6.5% (3) strongly agreed and 8.7% (4) agreed. The results show a significant correlation between "I would be glad to change the team" and "I feel that other teams were more creative than us" and a negative correlation with "Our team was very creative".

In general, the results show that most of the children felt very creative, valued their teams and its creativity. The desire to continue to study robotics was not correlated to any creativity or teamwork statements (82.6% (38) strongly agreed and 8.7% (4) agreed with the statement "I will be happy to participate in this program next year"). The Fisher's exact test indicated no relationship between the child's gender and child's age and response to each statement in close-ended part of the interview ($p > 0.05$), meaning that neither the child's age nor the child's gender influenced the responses about child's feelings about himself, his team and others' creativity.

Findings of Kucuk & Sisman (2020) showed that for secondary school children gender has effect on robotics learning desire and confidence, where female students had significantly less desire and less confidence to learn robotics than male students. Our results for younger age show that there is no gender related influence towards desire and confidence to learn robotics for boys or girls.

Master et al. (2017) study revealed that 6-year-old children already hold stereotypes that boys are better at robotics and programming than girls. However, children who were provided the experimental treatment showed no significant gender differences for interest in programming, interest in robots, or self-efficacy with robots. Their findings are similar to our results for children aged 5 - 7.

5. Conclusion

Creativity is the act of turning new and imaginative ideas into reality. It involves two components: originality and functionality. Both are encouraged in RE. It is essential to choose a final challenge that will encourage children to be creative. That is why teachers and EAR project managers should invest their time and effort in choosing a correct topic. Our finding revealed that children were very motivated, created diversity of projects and many original solutions.

To succeed in our rapidly changing world children must learn to think creatively, work collaboratively, communicate clearly and learn continuously. RE allows to do all those things. Our findings show that majority of children felt very creative and appreciated their team's creativity, most of children understood what the need of the project was, what the challenge was and what they created. The results showed that children learned to communicate, to make effective age-appropriate subject presentation and to justify their decisions. In their descriptions they communicated clearly, showed robotics and scientific literacy, fluently used robotics' related terms, correctly used technical and scientific terms and facts, and showed a correct understanding of their meanings.

Additional findings of this research revealed that a properly chosen final project in RE can be used to promote inquiry-based science education. The analysis of the relevant for the project facts, the needs and the technological challenge, demonstrated an understanding of basic scientific terms, concepts, and facts, revealed a wide scientific knowledge of the participants, a great variety of the needs and a diversity of the ideas how to solve the problem. The scientific needs and technological challenges were well explained, and in majority of cases well understood, increased child's knowledge of science in general and participant's knowledge in the field of astronomy or Moon astronomy in particular.

Children's passion and enthusiasm for the final projects reached its culmination at the Robotics Day. Teams were happy to present the models, gladly explained the need and the solution, and demonstrated the robots. Participation at the Robotics Day generated a sense of community among the teams. It was common to see members from one team assisting another team to find a correct word for explanation or helping in presentation.

However, one of the main findings of this study is that the majority of children consider robotics education as interesting activity and want to continue their robotic education in the next school year (91%). The results showed that there is no gender or age-related influence towards continuation of robotics studies. This quite significant fact should be considered and used by EAR stakeholders to close the gender gap in STEM.

The results of this study provide evidence that participation in RE in early childhood can encourage children to think creativity and invent new things, can stop steering girls away from science and engineering, can promote inquiry-based science education and increase positive attitudes about learning technology, science and robotics.

This study has several limitations. It should be taken into consideration that only posters of first graders were used to measure diversity and originality of the solutions. The methods employed in this study were time-consuming therefore the number of participants who answered the survey questions was only 46. Also interviews with children were not conducted using a random sample but a sample of children who volunteered to answer the survey or were randomly selected by the project manager.

The design of EAR programs with consideration for the results and proposals presented in this paper will have a variety of positive effects on educational achievements of our children. Teachers and schools must implement education outcomes of this study to promote creative thinking, allowing students to learn how to think, to problem-solve and investigate, to make scientifically justified decisions, to work in teams valuing both their own work and that of others.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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