Usability Evaluation of Educational Robotics

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ABSTRACT

The study attempts to identify the joy and satisfaction of children through their interaction with educational robotics, as well as the ease of use and learning of robotics. It focuses on the challenge of new experiences, the sense of achieving new goals, enhancing outcomes, innovation, the joy of creation, and teamwork. An educational robotics program is implemented and offered to 120 children aged between 9 and 15, who constitute the sample of the research. Following usability evaluation techniques, descriptive statistics were used to analyze the results. The main finding of the research is that the majority of participants were satisfied with their involvement in the program, felt comfortable, and found the programming and construction processes to be straightforward. Additionally, they had no issues working in teams to complete the tasks and would wholeheartedly recommend it to others. The analysis of additional statistical results in relation to previous research findings and the general theory serves as its conclusion.

CCS CONCEPTS

• **Human-centered computing** → Human computer interaction (HCI); HCI design and evaluation methods.

KEYWORDS

Educational Robotics, Usability evaluation, STEAM,

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1 INTRODUCTION

The integration of technology and childhood [1] is the most important issue of this research study, as the role of educational robotics is exploring, especially for children, in human-mechatronic interactions. It is clear that there are two dominant trends at the beginning of the third millennium. The rapid development of technology and changes in education and teaching models for children's education. Minimizing the size of the system while maximizing computing power has led to the rapid development of this technology. Understanding how people take advantage of the new digital world and how the technology is used effectively in everyday activities from infancy is one of the biggest challenges in the coming years.

Robotics and STEAM learning have entered education as the next big thing. It is widely understood as an educational approach that includes science, technology, engineering and mathematics. STEAM education aims to introduce more students in digital technologies, developing at the same time a STEAM potential, and increasing STEAM literacy for all students. To increase the size of the STEAM potential, are needed interdisciplinary strategies to integrate STEAM knowledge and skills. Students will learn to implement STEAM skills in contexts that connect school, society, work, and global business as it integrates academic STEAM concepts and real-life lessons. Educational Robotics is an effective project-based learning tool that combines STEAM, programming, computational thinking, and engineering skills. Robotics enables students to use decision-making tools to explore how technology will help real life [2].

Through educational robot learning, students can control, question and scrutinize technology. Students learn how technology works by designing, building, programming, and documenting autonomous robots. They apply the knowledge and skills acquired at school, in useful and interesting ways. Educational robotics offers many opportunities, not only in STEAM, but also in many other disciplines such as education, social sciences, music, and art. An educational robot is a learning tool that enhances a student's real-world experience. Most importantly, through hands-on practice and technology integration, educational robotics provides a fun and engaging learning environment. The learning environment encourages students to acquire the skills and information they need to achieve their goals and complete projects of interest to them.

Educational robotics as a teaching method is related to classical constructivism, especially constructivism. According to constructivist theory, students create new concepts and ideas through active participation and participation in authentic activities based on what they already know. According to constructivism, people develop their knowledge most effectively when they are actively involved in designing and constructing (manually and digitally) real meanings that are meaningful to themselves or others [3].

2 STATE OF THE ART

Students have investigated the specific benefits that can be obtained from the opportunities provided by educational robotics, but the study literature is quickly expanding. It is also distinguished by a high degree of heterogeneity in terms of research institutions, particularly in terms of relevant goals. Overall, students' views toward the use of educational robots are extremely positive. Beran et al. [4] discovered that children ascribe various cognitive, behavioral, and emotional characteristics to the robots they learn, whereas Ruiz and Aviles [5] discovered that students' satisfaction with using

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robots increased with their interest. In terms of studying, science, and improving their research abilities. Liu [6] investigated students' views of educational robots and discovered that the majority of them found it especially fascinating, and learning to use them could be a reason for pursuing a career in the tech industry [30].

Apiola et al. [7] found that after completing a robotics exercise, students' interest in STEAM increased, showing improved confidence levels and improved problem-solving abilities. Varnado [8] discovered that after eight weeks of participating in a robotics project, students reported higher levels of self-confidence, as well as better planning and problem-solving abilities. Furthermore, after participating in a robot competition, Welch [9] surveyed students' opinions on the societal impact of science and discovered that they had a positive attitude about technology and science. Kandlhofer and Steinbauer [10] discovered that children thought educational robotics apps improved their mathematical and scientific inquiry skills, working in team, and social skills.

Serholt and Barendregt [11] investigated the attitudes of students who participated in an educational robotics workshop and found that the majority had positive attitudes toward robots with anthropomorphic features while feeling comfortable interacting with them, while Cross et al. [12] suggested that the most important factors are the curiosity, interest, perceived value and identity of educational robots. According to Kaloti-Hallak et al. [13], students who engaged in robotics projects had a particularly positive outlook toward similar applications and were highly motivated to participate in such activities, particularly among females. Theodoropoulos et al. [14] investigated children's attitudes towards educational robots. They concluded that these apps had a particularly positive impact on student engagement levels. It also affects problem-solving skills, creativity, engineering literacy, and STEM programming and understanding [30].

The role of teachers in effectively integrating and operating educational robots in the educational process is decisive. To achieve significant learning outcomes, the educational process should be student-centred and take into account student characteristics. In this approach, learning is always indirect, as the teacher only intervenes in a consultative manner, allowing students to check that their decisions are correct.

Through the development of educational robotics, significant growth in computational thinking skills has been observed. In particular, students involved in educational robotics were able to understand abstract concepts and develop them to a fairly satisfactory level. This is because they were able to correctly identify and describe the general behavior of the robot and its general programming structure. In addition, students require less time to understand and grasp generalized concepts, and it turns out that they can reasonably provide more general solutions covering a wider range of cases. Regarding the concept of segmentation, thanks to the continuous introduction of educational robots, students are able to understand and develop it well, as they are often able to correctly segment a problem into smaller parts. For the concept of algorithm, let students have a deeper understanding, and continue to carry out activities under the guidance of the teacher, so that students can master it. Regarding the meaning of unity, it was found that this was the concept that the students played with and executed more from the beginning than all the other concepts.

Research has shown that educational robotics can improve preschool children's cognitive abilities by developing abilities such as self-monitoring, problem solving, critical thinking, decision making, and computational thinking [26]. In addition, international organizations dealt with the skills that a 21st century student should possess. These skills include creativity, communication and collaboration, research skills, critical thinking, problem solving and decision making, digital citizenship and technological functions and skills, and computational thinking. All these skills are promoted through the advantages provided by Information and Communication Technologies (ICT) [27]. The concept/skill of coding, which comes through programming, began to be incorporated into preschool education. Programming a robotic system, educational robot, is inextricably linked to problem solving. The student is asked to program a robot for a specific task, this programming can be correct or incorrect. If it's right the student moves on, if it's wrong he gets into the logic of solving a problem, works collaboratively to solve it, uses code, his imagination and creativity to solve a problem he's involved in. Therefore, it is something that gives him motivation for learning and confidence that he can succeed [28]. Research that has been done on preschool children has shown that through educational robotics, children use mathematical concepts related to movement in space, counting and measurement. Children use spatial, metric and numerical concepts that help them program robotic systems and thus through educational robotics children are given the opportunity to engage in mathematics in a more engaging way [29].

By conducting an extensive literature review, it becomes evident that there is a lack of comprehensive research on the usability of educational robotics systems. This research aims to investigate the usability of educational robotics systems by analyzing it in its fundamental dimensions.

3 RESEARCH METHODOLOGY

3.1 Design and participation

This study was carried out using a quantitative research approach, using data collected from a questionnaire, which was distributed and completed by 120 trainees. The research sample consists of 120 students aged 9-12 who participated in an educational program related to educational robotics. After completing the 10-week program, which included exercises and applications with robotic systems, they evaluated the experience using a suitable usability evaluation questionnaire.

The questionnaire was specially prepared by the researchers for research purposes, and it concerns students' attitudes and attitudes towards educational robots. It consists of 4 parts, the first part captures the demographic characteristics of the sample, the second part examines how enjoyable it is to participate in the learning, the third part focuses on the ease of use of hardware and software, and the fourth part examines the ease of learning. After collecting the data through the questionnaire, descriptive statistics and inductive statistics were used for statistical processing and correlation testing. The choice of using questionnaires for quantitative research is based on the fact that this method yields objective data that reflect reality and have a high degree of reliability. In this way, specific trends for a wider population (in this case, education) can be seen. The results are analyzed using a special "statistics" package.

The objectives that come through this aim are to identify the adoption level of the robotics education and especially to:

- Explore what is the degree of pleasure from participating in an educational robotics program
- Identify if it is easy to use the software and hardware required
- Explore if it is easy to implement real-life scenarios

3.2 Validity and reliability check

Considering that the purpose of the study was to determine the enjoyment and satisfaction of participation, as well as the ease of use of the robot, the collection of relevant information was carried out using an ad-hoc instrument (questionnaire). Given that the data collected are quantitative, students can be reached through ongoing pilot projects, data can be collected from a sufficient number of students (sample), and the time available to conduct research and process the results is relatively limited. The first research method is descriptive, quantitative, selective and is the basis for the implementation of its results and is implemented using a questionnaire instrument.

Measurements must have certain characteristics and satisfy certain conditions in order to be used as a research method or tool. Two of them are critical, the most significant of which are validity and reliability. The degree of stability of the measurement, that is, the degree of agreement between repeated measurement results under the same circumstances, is indicated by reliability. Validity refers to whether or not a research tool measures what it is intended to measure, and if so, whether or not we use it to test it. This research took into account all necessary precautions to ensure its validity and reliability. When using questionnaires, reliability issues frequently emerge because the questions are vague and incorrectly filled out. To answer this issue, a pilot study was conducted. The questionnaire was initially started by five participants who completed it. Some questions were added with extra parameters as a result of this procedure, while others were rewritten. The introduction to the questionnaire was also deemed too lengthy for this group, so it was cut. However, its content is conveyed by the researcher in such a manner that he does not need to read it but must be aware of it. As a result, all questions in the questionnaire are clearly worded and designed, and the possible answers will provide us with reliable and trustworthy information about the research topic while minimizing problems in statistical analysis. Questionnaire questions are also placed in the section corresponding to the subject of study, and a prediction was made to complete the questionnaire in 20 minutes. Questionnaires based on the aforementioned studies, literature, and research questionnaires were distributed to a subset of trainees, who were also asked to name the major factors of happiness and satisfaction and the technology's simplicity of use as a result of participation in the training program. This fact successfully boosts the credibility of a specific tool. Furthermore, not asking for survey participants' names and other personal information, as well as making every effort to make the questionnaire questions simple to understand and not too lengthy, helped to ensure reliability and validity.

3.3 Questionnaire structure

A four-point scale with four possible answers was selected as the evaluation scale in the questionnaire: two positive (a lot and very much) and two negative (few and not at all). Using 4-likert values scale is a common practice to record beliefs, values, motivations, and other aspect of human behavior [15]. The reason for not having an average response is to prevent the accumulation of neutral responses, encouraging a response distribution between negative and positive responses. The second part of the questionnaire (including the participation reward) scored the four points of the scale as follows:

1 = Not at all
2 = A little
3 = Enough
4 = Very much

The scope of the research and the group responsible for maintaining it are briefly mentioned at the beginning of the questionnaire, as well as the confidentiality of the information and instructions for completing the survey. The questionnaire was divided into two sections, the first dealing with general information about the trainees and the second with specifics about participation in the robotics training program.

Among the general questions, it was thought appropriate to ask about gender, age, housing, and upbringing, as these were crucial to the results. The second section of the queries delves into the specifics of the educational robotics process's implementation.

Questions 6, 7 and 8 ask if they are using computer at home, how often and for which reason. Questions 9, 10, 11 and 12 ask for previous knowledge on programming of robotic systems and algorithms including also Lego devices. Questions 14, 15, 16, and 17 identify the desire to participate and factors that may inhibit group functioning, as well as the potential problems they may create, and Questions 13, 18, 19, 28, 29, and 30 ask about the pleasure and the satisfaction of participation. Questions 20 and 21 attempt to determine how easy it is to use the system and 22 how easy it is to build the constructions. As empirical method is an important factor in research. Finally, questions 23, 24, 25, 26, and 27 refer to how easy it is to implement the scenario to solve the problem posed. Therefore, questions 20 to 27 can be said to fall into the categories of usability and learnability. The custom questionnaire is based on the structured USE (Usefulness, Satisfaction, Ease of Use) questionnaire proposed by Lund [16] as a tool to classify user responses into usefulness, ease of use, satisfaction, and learnability [30].

4 EXPERIMENTAL DATA

The sample were 120 children, 81 (67,57%) boys and 39 (32.5%) girls. According their ages, the majority were in the 9-11 age group with 49.2%. In the 12-13 age group were 34.2% and in the 14-15 age group were 16.7% (Figure. 1).

Of the 120 children, 2 (1.7%) mothers had primary education, 43 (35.8%) had not completed secondary education, and 75 (62.5%) had secondary or higher education. As for fathers, among the 120 children in the sample, 1 (0.8%) had graduated from primary school, 61 (50.8%) had not completed secondary education, and 58 (48.3%) had higher education or above.

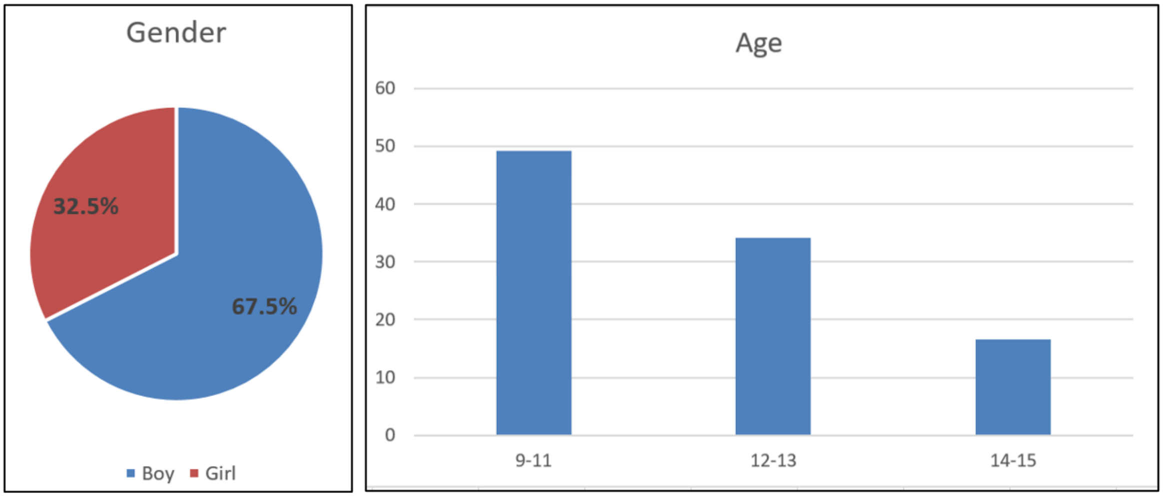

Figure 1: Age and Gender of sample

Table 1: Questions related to previous knowledge on programming and robotics

Questions	Symbolism	Avg Score (1-5)	Std. Deviation
Have you ever used Lego?	A9	2.63	0.618
Did you know what Robotic is?	A10	3.06	0.401
Did you know PC programming?	A11	2.71	0.474
Did you know what an algorithm is?	A12	1.95	0.613

Table 2: Questions related to desire of participation and work in a team

Questions	Symb	Avg(1-5)	Std.
Did you know the rest of your team members?	A14	2.97	0.61
Have you worked with them again?	A15	2.13	0.66
Did you feel moral shyness (shame) when you joined your team with other members?	A16	1.26	0.41
Do you feel that you are being skipped within your team?	A17	1.45	0.45

Table 1 shows the variables reported by the students regarding programming and robotics prior knowledge, and it is clear that all questions have a mean greater than or equal to 2.5, which indicates that the respondents have some programming and robotics knowledge. All score values are calculated on a scale ranging from 1 to 5, based on the Likert scale.

The second section includes questions about the respondents' desire to participate in and work in teams. Table 2 lists variables related to students' willingness to participate and work in small groups, indicated that they knew many other members of their group (2.97), but indicated that they had worked with them a few times before (2.13). Finally, respondents responded that they did not feel excluded from their own group (1.45) or moral cowardice (shame) when they joined their group with other members (1.26).

The third section included questions about respondents' enjoyment and satisfaction with participating in the group. Table 3 lists the variables associated with the enjoyment and satisfaction of student participation.

In particular, respondents answered that they liked the workshop very much in general (3.69), were very willing to attend a robotics workshop (3.67), felt very happy every time they participated in a workshop activity (3.58), and would recommend the workshop to a friend (3.43). On the other hand, the respondents also expressed that they are not afraid of failing to meet the course requirements (1.68), nor do they find the courses boring (1.56).

The fourth section includes questions related to the ease of use of the programs and blocks by the respondents. Table 4 shows the variables for reported student ease of use of the software and modules. Respondents responded that they clearly remembered which blocks to select for each command (3.28), that assembling the tracked machine was easy (3.27), and found the computer program they used to program the robot to be very simple (3.16).

The fifth section includes questions about the ease with which the respondents implemented the scenarios. Table 5 lists the variables for reported ease of application of the scenarios by students. Respondents answered that they plan to have the car turn 90° easily

Table 3: Questions related to pleasure and satisfaction from participation in a team

Questions	Symb.	Avg (1-5)	Std. Dev.
How much did you want to participate in the robotics seminar?	A13	3.66	0.52
How much happiness do you feel every time you participate in a seminar activity?	A18	3.58	0.46
How afraid were that you wouldn't be able to meet the requirements of the lessons?	A19	1.68	0.57
Have you been tired or bored during the lessons?	A28	1.56	0.39
Did you like the seminar on the whole;	A29	3.69	0.34
Would you recommend it to a friend of yours?	A30	3.43	0.51

Table 4: Questions related to ease of using software and blocks

Questions	Symb.	Avg (1-5)	Std. Dev.
How easy was the PC program you used to program robotics?	A20	3.16	0.81
Do you remember which blocks to choose for each command?	A21	3.28	0.80
How easily did you mount the vehicle with the tracks?	A22	3.27	0.77

Table 5: Questions related to ease of scenario implementation

Questions	Symb.	Avg (1-5)	Std. Dev.
How easily did you plan the vehicle to turn 90th?	A23	3.10	0.82
How often did the vehicle escape from what you wanted to do?	A24	2.74	0.79
If the vehicle was out of route how easily you corrected the error?	A25	2.95	0.69
When you used a distance sensor how often was the vehicle's impact on an obstacle?	A26	2.17	0.80
How easy did you program the vehicle with the color sensor follow the black line?	A27	3.05	0.91

(3.10), program the car with color sensors to easily follow black lines (3.05), and if the car drifts, they can easily correct mistakes (2.95), from what they want to do Yes, the car moves away quite often (2.74), and when you use the distance sensor, the car hits obstacles not very often (2.17).

5 DISCUSSION

The results showed that the usability of educational robotics is at a high level. Children between the ages of 9 and 15 effectively use the modern tools and experience great satisfaction from using them. The study concentrated on how students interacted with the robots and how readily they could be operated. According to the findings, the students easily operated the robot, despite initially believing it was difficult and impossible. The conclusion is the same with the result of Kim and Lee [17] study, where students trained how to control a robot in just 20 minutes. Highfield, Mulligan, and Hedberg [18] found also that even when children had no prior experience with robots, they learned how to work with them and performed short-term learning.

After the students grasped the purpose of the robot, they were instructed to carry out a number of tasks with the assistance of the robot. According to the findings, students in robotics educational settings successfully accomplish cognitive goals by building themselves by experimenting with new knowledge. They are more willing because the lessons are more easily accessible to them. Other studies, such as Barker and Ansorge [19], which state that robotics is effective in teaching science, engineering, and technology, support these findings. Kim and Lee [17] believe that further use of robots as educational tools could produce positive results in this area. Robots, according to Highfield, Mulligan, and Hedberg [18], can improve students' mathematical idea development, translation, and measurement processes earlier than previously thought. They went on to say that the robot offered many different problem-solving strategies and encouraged the students to think abstractly. These cognitive processes are an essential component of the formation of cognitive structures in mathematical research. Furthermore, Miglino et al. [20] claimed that by expanding their knowledge, the robot group outperformed the other group.

Robots make lessons more appealing to children, increasing their mood and motivation to learn. Learning through gamification using the robot encourages students to participate in the lesson and work together, improving their interpersonal and communication skills and giving them more confidence. This is also supported by the findings of a study conducted by Kim and Lee [17], which found that using robots improved students' interest and curiosity in mathematics, as well as their engagement in lessons, encouraging them to be more active in activities. They also reported that the participation rate of the students who worked with the robot stayed high even after three months. According to a research conducted by Highfield, Mulligan, and Hedberg [18], students are eager to participate in their activities, and their interests are invaluable in motivating them. Meanwhile, Miglino et al. [20] emphasize the importance of using hardware and software in leisure learning.

The provided research discovered that, among other things, robotics improved students' cognitive and cognitive abilities by encouraging creativity, self-expression, and the development of investigative interests. This is also consistent with earlier research showing that the use of educational robots helps to develop and deepen children's cognitive environments, as well as cognitive skills [21, 22]. Robotics is also thought to benefit children's social skills development by encouraging communication and cooperative learning, as evidenced by group participation corroborating studies in the pertinent international literature [23, 24].

A particularly significant finding is that educational robots have a positive effect on students' attitudes, specifically their willingness to engage in group work without hesitation or fear. Children's systematic participation in educational robotics applications can help to raise interest in science and degrees of intrinsic stimulation of STEM knowledge [19, 25].

To summarize, a robot possesses the necessary characteristics to be a valuable learning tool, and with appropriate learning methods, it can become part of a curriculum and be used in various educational activities and modules on various subjects. As a result, teacher-assisted robotics is a novel strategy that can assist students in learning more easily while also having fun through experimentation and experience.

It is important to mention the limitations of the specific research. The study was limited to a relatively small sample size, which could be expanded in the future to include a larger number of students. Additionally, incorporating other research methods could strengthen the study. Furthermore, it is recommended to integrate other modern technologies, such as 3D printing, scanning, and Artificial Intelligence, into educational programs alongside robotics. It is crucial for the new generation to engage in educational programs that cover a wide range of technologies, as they will be called upon to support them in the future.

6 CONCLUSION

This paper describes new learning methods created using robotics educational tools for teaching young students, which assist students in becoming acquainted with robotics as an engaging experience. Educational machines are part of constructivism from a pedagogical standpoint. Student involvement in robotics results in two kinds of activities: constructive and procedural. Robotics in education is a modern educational environment in which students construct and program robots using simple pre-literate visual language. Solving a particular scenario for pupils requires a combination of patience, imagination, ingenuity, method, and a great deal of effort. By developing general cognitive skills, it emphasizes the significance of teamwork in building robots, tackling new concepts, and completing or failing tests.

Children dislike theory, according to past experience. Otherwise, they prefer to begin work instantly without regard for definitions or general principles. In any event, practice cannot substitute the "theoretical" principles and qualities imparted by definition precision and completeness. The objective remains conceptual knowledge, as well as a grasp of rules and methods. The significance of exercise, methods, and techniques are known. The importance of experience in learning and assimilation cannot be overstated. Everyone learns in their own unique environment, building on their existing knowledge. To develop novel functional backbones, this knowledge must be inspired and extended. There is, of course, no distinction between theory and reality. The two are inextricably connected, resulting in bi-directional operation. Draw general conclusions, elevate them to a new theoretical level, and open up new areas of practice through practice. Learning with educational robots is a creative and fun method to learn basic math and computer science ideas.

To learn, a child must first have a desire and an interest in the topic being taught. To stimulate the child's attention, activities must be tailored to his requirements, hobbies, inclinations, and abilities. When used properly, educational robots in teaching can help create constructive learning environments by providing authentic learning activities incorporated in the curriculum as well as open-ended problem-solving processes that occur in the real world. Children require learning experiences because learning is the process of reorganizing existing knowledge and generating new knowledge. Encourage students' self-expression and personal involvement in the learning process, and use robotics to support their social interactions.

REFERENCES

[1] Gerlach, J. 2012, STEM: Defying a Simple Definition, NSTA Reports, National Science Teacher Association, viewed June 2015,

[2] Lavicza, Z.; Weinhandl, R.; Prodromou, T.; Anđić, B.; Lieban, D.; Hohenwarter, M.; Fenyvesi, K.; Brownell, C.; Diego-Mantecón, J.M. 2022 Developing and Evaluating Educational Innovations for STEAM Education in Rapidly Changing Digital Technology Environments. *Sustainability* 2022, *14*, 7237. https://doi.org/10.3390/su14127237

[3] Papert, S. 1991. Situating Constructionism. In I. Harel, & S. Papert (Eds.), Constructionism: Research reports and essays (pp. 1-11). Norwood, NJ: Ablex.

[4] Beran, T. N., Ramirez-Serrano, A., Kuzyk, R., Fior, M., & Nugent, S. 2011. Understanding how children understand robots: Perceived animism in child–robot interaction. International Journal Human-Computer Studies, 69(7–8), 539-550.

[5] Ruiz-del-Solar, J., & Aviles, R. 2004. Robotics courses for children as a motivation tool: The Chilean experience. *IEEE Transactions on Education*, 47(4), 474–480.

[6] Liu, E. Z. F. 2010. Early adolescents' perceptions of educational robots and learning of robotics. *British Journal of Educational Technology*, 41(3), 44-47.

[7] Apiola, M., Lattu, M., &Pasanen, T. A. 2010. Creativity and intrinsic motivation in computer science education: Experimenting with robots. *Proceedings of the 15th annual conference on Innovation and technology in computer science education* (ACM), 199-203.

[8] Varnado, T. E. 2005. The effects of a technological problem solving activity on FIRST LEGO league participants' problem solving style and performance, Doctoral dissertation, Virginia Tech.

[9] Welch, A. G. 2007. The effect of the FIRST Robotics Competition on high school students' attitudes toward science, Doctoral dissertation, University of Kansas.

[10] Kandlhofer, M., &Steinbauer, G. 2016. Evaluating the impact of educational robotics on pupils' technical-and social-skills and science related attitudes. *Robotics and Autonomous Systems*, 75, 679-685.

[11] Serholt, S., & Barendregt, W. 2014. Students' attitudes towards the possible future of social robots in education. *Workshop Proceedings of ROMAN*, 223-226.

[12] Cross, J., Hamner, E., Zito, L., Nourbakhshh, I., & Bernstein, D. 2016. Development of an assessment for measuring middle school student attitudes towards robotics activities. *Frontiers in Education Conference* (FIE), 1-8.

[13] Kaloti-Hallak, F., Armoni, M., & Ben-Ari, M. M. 2015. Students' attitudes and motivation during robotics activities. *Proceedings of the Workshop in Primary and Secondary Computing Education* (ACM), 102-110.

[14] Theodoropoulos, A., Antoniou, A., & Lepouras, G. 2017. Teacher and student views on educational robotics: The Pan-Hellenic competition case. *Application and Theory of Computer Technology*, 2(4), 1-23.

[15] DeVellis, R.F. 2003. Scale Development. Theory and Applications. *Applied Social Research Methods Series, Vol. 26,* Sage Publications: London.

[16] Lund, A. M. 2001. Measuring usability with the USE questionnaire. Usability interface, 8(2), 3-6.

[17] Kim, S., & Lee, C. 2016. Effects of robot for teaching geometry to fourth graders. International Journal of Innovation in Science and Mathematics Education (formerly CAL-laborate International), 24(2).

[18] Highfield, K., Mulligan, J., & Hedberg, J. 2008. Early mathematics learning through exploration with programmable toys. *Paper submitted to PME*, 31(2).
[19] Barker, B. S., & Ansorge, J. 2007. Robotics as means to increase achievement scores in an informal learning environment. *Journal Research on Technology in Education*, 39(3), 229-243.
[20] Miglino, O., Gigliotta, O., Ponticorvo, M., & Nolfi, S. 2008. Breedbot: an evolutionary robotics application in digital content. *The Electronic Library*, 26(3), 363-373.
[21] Kazakoff, E., Sullivan, A., &Bers, M. 2013. The effect of a classroom-based intensive robotics and programming workshop on sequencing ability in early childhood. *Early Childhood Education Journal*, 41(4), 245–255.
[22] Khanlari, A. 2013. Effects of robotics on 21st century skills. *European Scientific Journal*, 9(27), 26-36.
[23] Scholz, H., & McFall, K. 2011. Comparison of an Introductory Engineering Course with and without LEGO Mindstorms Robots. *Technology Interface InternationalJournal*, 11(2), 61–64.
[24] Varney, M. W., Janoudi, A., Aslam, D. M., & Graham, D. 2012. Building young engineers: TASEM for third graders in Woodcreek Magnet Elementary School. *IEEE Trans Education*, 55(1), 78-82.
[25] Bers, M. U., Flannery, L., Kazakoff, E. R., & Sullivan, A. 2014. Computational thinking and tinkering: Exploration of an early childhood robotics curriculum. *Computers & Education*, 72(0), 145–157.
[26] Di Lieto, M. C., Pecini, C., Castro, E., Inguaggiato, E., Cecchi, F., Dario, P., ... & Sgandurra, G. 2020. Empowering executive functions in 5-and 6-year-old typically developing children through educational robotics: An RCT study. *Frontiers in psychology*, *10*, 3084.
[27] Çakır, R., Korkmaz, Ö., İdil, Ö., & Erdoğmuş, F. U. 2021. The effect of robotic coding education on preschoolers' problem solving and creative thinking skills. *Thinking Skills and Creativity*, *40*, 100812.
[28] Somuncu, B., & Aslan, D. 2021. Effect of coding activities on preschool children's mathematical reasoning skills. *Education and Information Technologies*, 1-14.
[29] Shumway, J. F., Welch, L. E., Kozlowski, J. S., Clarke-Midura, J., & Lee, V. R. (2021). Kindergarten students' mathematics knowledge at work: the mathematics for programming robot toys. *Mathematical Thinking and Learning*, 1-29.
[30] Tsagaris A. 2018. Educational robotics and human interaction with mechatronic systems, Dissemination, Hellenic open University.

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