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A review on educational robotics and creativity

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Abstract

The purpose of this thesis is to investigate if and to what extent creativity is linked to educational robots. More specifically, it examines the role that educational robots can play in promoting and enhancing creative thinking and other creative processes, such as computational thinking, through the use of artificial intelligence. To achieve this goal, a literature review is carried out on studies that have been conducted, mainly last five years and are applied practices of using educational robots and STEM learning in various educational settings, showing how they can encourage creativity and problem-solving in students. Search engines – databases – such as Google and Google scholar were used as a research tool. The results of the review showed that the use of educational robots develops skills linked to creativity, such as reflection, collaboration and innovation, and is therefore a useful educational-technological tool in the hands of the modern teacher. Finally, possible directions for future research and educational practices on this topic are suggested.

Keywords: Educational Robotic; STEM; Artificial Intelligence; Computational Thinking; Creativity

1. Introduction

A key skill that is important and should be mastered by students at every level of education is the ability to think creatively (Monica et al., 2021). However, initially examining the concepts discussed in the article we come across educational robots. These are defined as physical or virtual systems specifically designed and produced for use in educational environments, with the aim of enhancing learning and understanding in topics such as programming, engineering, electronics and other technology-related fields. Educational robots usually come with educational software that allows users to program, test, and explore their capabilities with a gameplay approach (Benitti, 2014).

Regarding the second concept addressed in the article, which is creativity, this in education is defined as the ability of students to produce new ideas, solutions and products that are original, useful and respond to specific needs or challenges. The creative process involves exploring, analyzing, reconstructing and evaluating ideas and proposals (Sternberg & Zhang, 2009). Creativity in education is encouraged through a variety of approaches, such as need-based problems, research games, collaborative activities and challenges.

Educational robotics provides a rich learning environment that combines STEM principles with hands-on experience and creative thinking. According to Fajrina et al. (2020) integrated STEM learning is one of the appropriate approaches to be applied in the learning process as an effort to cultivate 4C skills (critical thinking, creativity, collaboration and communication). Jawad et al., (2021) in their research obtained results that with STEM learning they could develop innovative thinking, improve the performance of their students, because with STEM learning an atmosphere of passion can be created that attracts students to the field, motivates learning, creativity and innovation.

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The aim of this literature review is to demonstrate that educational robots can be effectively combined with creativity in education through problem-solving, creative applications, design and construction as well as the collaborative process.

2. Literature Review

Elvis Mazzoni and colleagues (2020) studied the effectiveness of the Ozobot robot as an interactive educational tool to enhance their creative thinking. The study involved 171 children aged between 9 and 10 from two primary schools in central and northern Italy. The students were randomly assigned to three groups: the Single Work group, the Pair Work, and the Control Group. The children were asked to encode Ozobot's movements by coloring the blank spaces of a maze on paper with predefined color codes to define a path and complete the task. The results showed that the use of the Ozobot educational robot significantly improves children's creative thinking abilities in both experimental groups. It was also observed that children who performed the task alone with the educational robot significantly improved their creative thinking potential, compared to those who performed the task in pairs and with the control group. This may be because students working in pairs were more interested in avoiding conflict than in finding the best and most creative solution to the problem. As socio-cognitive conflict is seen as a motivator of creativity, avoiding it by adopting a solution without reflection and discussion may not have allowed children working in couples to develop their solutions in a more creative way.

Çakır et al. (2021) conducted a study with the aim of determining the effect of robotics and coding teaching on the problem-solving and creative thinking abilities of preschool children. The study was conducted in a kindergarten in Turkey's Amasia province and a total of 40 preschool students took part in it. The data was collected through the "Problem Solving Skills Scale (PSSS)" and "Creative Thinking Skills Test". The experimental process lasted four weeks and a total of 32 hours of class was conducted. During the procedure, the WeDo 2.0 Educational Robotics Kit was used in the experimental group, while in the control group activities were carried out with pen and paper. Participants in the experimental group performed educational robotic activities in online games, while those in the control group read stories from classic fairy tales and listened to songs. The results showed that teaching robotics and programming has provided a statistically significant contribution to preschool children's problem-solving skills compared to pen and paper activities. In addition, factors of imagination and originality in the field of language as well as factors of integration, addition of new elements and unconventional factors in the field of design were found to be statistically significant compared to the other factors.

In an earlier study, Park et al. (2015), sought to develop a type of robot-based learning with programming aimed at improving students' creativity and understanding satisfaction in primary school classrooms. The study participants were first-grade students at an elementary school located in Seoul, Korea. The school carried out four different experiential activities. One activity was training robots with programming. 26 students from four classes participated voluntarily in the research project. The robot class met for two hours a week for 12 weeks. To examine the research question, the effectiveness of this practice was investigated. Methodologically, a paired t-test with pre-test and post-test results was conducted to measure creativity. The training robot used for the study is a robot developed by a telecommunications company in Korea. The programming language was Scratch-type programming, which allowed students to easily learn and use the robot. To measure participants' creativity, the Korean Visual Creativity Test for Primary School Students (K-FCTES) was adopted. Results from the pre-test analysis to understand differences in creativity revealed that fluency ($p = 0.004$) and originality ($p = 0.027$) improved significantly. Second, class satisfaction was measured by descriptive statistics and the average was 4.45 out of 5.

The research of Sobhy Soliman (2019) focuses on robotics programs that can contribute to the development of students' creative thinking abilities and skills. The study used the experimental curriculum to investigate the effectiveness of the computer-aided educational robotic training program in developing students' creative thinking skills. The sample of the survey consisted of 30 students attending the Second Gymnasium at Manba'a El-Hekma School in the province of Dhofar, during the academic year 2018-19. The students were divided into 2 equal groups, the experimental group and the control group. The students of the experimental group were trained in the programming of educational robotics using the computer training program. In both groups, before and after the completion of the training, the Torrance creative thinking test was applied, as well as the product evaluation card to measure students' skills in producing creative projects based on robotics programming. The results showed that there are differences with a statistical indication at a level of 0.5 between the two averages of the grades of the experimental and control groups, in favor of the former, between the measurements before and after the implementation of the Torrance test and the evaluation card of students' projects. The research recommended merging educational robotics and artificial intelligence in teaching and education, training teachers to use this technology and encouraging them to use it in teaching, and to include the online curriculum developed in this study in mainstream schools to develop creative thinking skills in students.

Kondrataviciene & Bolgova (2020) examine how the use of programmable robots in math lessons can help develop the creativity of primary school students. For the collection of qualitative data, the method of partially structured interview was chosen, after the necessary analysis of the literature. The survey was conducted in May 2020 and involved ten (10) teachers of different classes from Lithuanian primary schools. The outcome of the analysis of the interviews showed that primary school seeks to create favorable conditions (physical environment, psychological climate, experiences and impressions, scheduling, creative tasks and attitude of the teacher) for the development of students' creative abilities. The use of programmable robots in learning mathematics encourages and assists the visualization of a mathematical problem, the selection, classification and processing of information. It also helps to predict the strategy and order of solving a problem by selecting and applying creative methods of solving mathematical problems. Teachers perceive the benefits of creativity for students' personal development in the areas of knowledge application, thinking, motivation and development of personal skills and competences. In order to develop their students' creativity, teachers in mathematics class organize robot programming activities with which students are encouraged to discuss and exchange ideas, leave them free to choose methods and strategies for completing tasks, and provide mathematical exercises with more than one solution, thus encouraging them to find unusual and original ways to solve a problem.

Vistara et al. (2022) demonstrated, through a systematic literature review, how the construction of educational robots by students contributes to the cultivation of creative thinking. Specifically, they approached the topic through a machine design process with a project-based learning model that aims to improve mathematical creative thinking skills. The Seckels had a similar direction et al. (2023) who through a literature review came up with some useful guidelines for developing computational thinking using the Bee-bot robot. More specifically, they find that although various proposals concern the development of computational thinking in the early years of schooling, educational robotics appears as an alternative. The Bee-Bot robot has been identified as a suitable resource for developing this type of thinking at an early age. For this qualitative study, 25 articles were selected and analyzed to give didactic orientation for the integration of computational thinking in mathematics lessons using the Bee-Bot robot (or similar). In a more general context, it was proven that Educational Robotics is used as an activity in which participants learn the basic principles of robotics, in a teaching environment based on creativity and experimentation. Thus, educational robots are designed and built and their creators learn to control them from the computer using a programming language and consequently making practical and very creative use of their computational-mathematical thinking.

In support of the above, and regarding the integration of educational robotics in mathematics lessons, older scholars such as Ocaña (2012) have stated that the construction and use of robots is an attractive and innovative opportunity for learning, as knowledge of mathematics and technology is applied in practice. Thus, educational robotics begins to gain space in education, and specifically in mathematics, drawing on various didactic topics related to the construction and programming of a robot. On the other hand, Roschelle et al. (2000) attribute the use of robots in classrooms to increased interest in mathematical and technological learning, reducing the existing gender gap in these discipline areas, and enhancing the development of skills such as problem-solving, creativity, and collaborative work.

In their research, Chevalier et al (2020) find that while previous work has proposed different models and frameworks to describe the underlying concepts of computational thinking (CT), very few have discussed how educational robotics (ER) activities should be implemented in classrooms to effectively promote CT skills development. To address this issue, The work of these researchers aimed to provide a functional framework-model for ER's activities taking into account two main aspects of CT, computation and creativity, integrated in the context of problem solving. As an experimental validation, the proposed model was used to design and analyze an ER activity aimed at addressing a problem often observed in classrooms: the trial and error loop, that is, an overinvestment in planning relative to other tasks related to problem solving. Two groups of primary school students participated in an ER activity using the Thymio educational robot. While one group completed the task without imposed restrictions, the other underwent an educational intervention developed based on the proposed model. The results suggest that (i) a non-didactic approach to educational robotics activities (i.e., unrestricted access to the programming interface) promotes a trial and error behavior; (ii) a programmed blockade of the programming interface enhances cognitive processes related to understanding problems, generating ideas and formulating solutions. (iii) Progressive adaptation of the programming interface exclusion can help students build a well-defined strategy for approaching educational robotics problems.

The article by Smyrnova-Trybulska et al. (2020) analyzes various aspects of the use of robotics in education and examines the level of preparation and motivation of students. The authors conduct a comprehensive review of research and scientific publications on the technological, didactic, methodological and human aspects of the use of robotics in education. The article presents the results of a survey conducted among participants at the third Silesian Science Festival 2019. The data were obtained from people who attended workshops and visited the exhibition stand presenting innovative digital technologies in education and business, organized by the Department of Humanistic Education and Auxiliary Sciences of Pedagogy of the Faculty of Ethnology and Education Sciences at the University of Silesia in Cieszyn, Poland. Respondents aged 6–15 were primary school students. The Photon robot is an interactive educational robot that introduces children to the world of new technologies through a mobile application and related experiences and experiments. It is intended for preschoolers up to 12 years old. The main advantage of Photon is learning the fundamentals of programming and using its features to support learning other topics (e.g. a foreign language). The results of the research contain a large amount of data which in general reflect the great influence that this educational robot had on the development of students' creativity, logical thinking and the ability to program at a basic level but also to understand the operation of the sensors with which a robot is equipped.

The study by Kewalramani et al. (2021) explores interactive robotic games (ER) with artificial intelligence (AI) interface for the development of children's exploratory literacy in early childhood educational settings. Arguments about the appropriate role of AI in early school education have received much attention when considering the potential of integrating technology into children's play and learning. Using Vygotsky's mediation theory and a design-based research methodology, teachers intentionally used robotic AI toys to encourage children (4-5 years old) to engage in experiential games. Data from interviews with teachers and children, observations and analysis of artifacts revealed how the children collaborated creatively with their peers to create a sustainable city in which they would live happily with their robot and their family. Children's play with the artificial intelligence robot encouraged exploratory literacy – specifically creative, emotional and collaborative research. In their main findings, the authors summarize how interacting and operating with an artificial intelligence robot could be complicated, but these interactions stimulate children's creativity, emotion, collaboration and related literacy skills.

Williams et al. (2019) conducted a hands-on survey of preschool students to teach children artificial intelligence concepts. Their study included a series of robotics workshops held in spring 2018 with children from four schools in the greater Boston area. More specifically, they developed an educational platform, "PopBots", in which children are trained and interact with social robots to indirectly learn three concepts of artificial intelligence: knowledge-based systems, supervised machine learning and genetic artificial intelligence. The researchers chose these topics because they relate to the kinds of AI algorithms that children are exposed to through smart games and entertainment apps. The PopBots activities took place in 5 classrooms and data was collected from 80 children aged four to six. The platform consists of a social robot toolkit, a programming interface on a tablet computer, and three hands-on assessment activities for young children to explore machine learning and reasoning algorithms. Children build their own LEGO robot characters using regular LEGO and LEGO DUPLO blocks. The robot is programmable but also has autonomous functionality. As the children go through each practical activity, the social robot talks to them – explaining the logic of the algorithm and encouraging students to try new things. As reflected by their performance in assessing artificial intelligence, the children seemed to understand its concepts well. The median score of children for their assessment of artificial intelligence was 70%. Also, of the three concepts of artificial intelligence examined, genetic AI proved to be the most creative and interesting for children – since it had the greatest participation. In the MusicRemix activity, chosen to show children that robots can be creative, instead of learning rules, the system produces a new output based on the children's input song. The children successfully combined different rhythms with the corresponding emotions that appeared on the screen (excitement, joy, sadness, surprise, fear, etc.) in order to teach musical emotions to the robot.

Concluding this chapter, we underline the role both of epistemology and STEM [19-26] as well as the digital technologies' contribution to education [29] via mobiles [27-28], robotics [30-31] and Games [32-37]. They are and powerful tool to enhance mental abilities to support to overcome learning difficulties and to develop creativity, along with educational robotics.

3. Conclusion

The present study is a literature review of the most representative research articles, which link educational robotics with the development of creativity. The findings of the studies that were studied reinforce the positive correlation between the inclusion of robotics and programming in the educational process with the cultivation of skills such as creativity. The participating students of the experimental groups showed statistically significant improvement in their skills such as creativity, originality, computational thinking, problem solving and teamwork when they came into contact with the educational robots or by programming them. Therefore, the effective and consistent utilization of educational robotics, by qualified teachers, as a teaching and learning tool has multiple benefits. With the right guidance and use, educational robots can be a powerful tool to promote creativity in education. The possibilities offered by the use of educational robotics do not only concern the modernization of the educational process but also the expansion of the boundaries and pedagogical possibilities of this field. The way of integrating educational robotics that can bring maximum effectiveness in cultivating students' creativity is an interesting field of study of future research.

Compliance with ethical standards

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Disclosure of conflict of interest

The Authors proclaim no conflict of interest.

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