Educational Robotics

Subjects: Robotics
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Educational Robotics arose, developed, and flourished at the crossroads of educational science and computer science to serve and contribute to both scientific fields. The research questions raised through Educational Robotics, implemented by activities designed by the theory of constructionism, concentrate on the creation of computational thinking skills, collaborative learning, and project-based learning, taking into account the social nature of the student-robot relationship. Programming skills, sequencing, scripting, and algorithmic thinking are the primary goals of ER. Furthermore, as an essential branch of educational technology, the ER area of study improves conventional teaching methods' quality and efficacy while also introducing pedagogical changes to enhance education.

Keywords: educational robotics ; computer vision ; educational tool

1. Introduction

In recent decades, education has been transformed and transitioned beyond the traditional learning process methods and is now enriched with procedures that make use of technological, mainly Information Communication Technology (I.C.T.), related tools. Many researchers studied the convergence of I.C.T. in education while highlighting the growing and successful incorporation between I.C.T. applications and teaching [1]. They provided clear explanations about the significance of its I.C.T. role, identifying the opportunities offered to teachers and students [2], resulting in a more useful and exciting learning process.

Over the years, rapid growth in robotics has been reported, improving a lot of developments in many fields, such as navigation and path planning [3][4], search and rescue applications [5], industrial applications [6], and entertainment. Considering the impact of the field, robots would inevitably be adapted for educational purposes also. Educational robotics is a field of study that aims to improve the learning experience through the creation, implementation, improvement, and validation of pedagogical activities [7][8][9]. Learning theory principles, constructivism and constructionism [10], are particularly bearing for the field of educational exploitation of robotics. According to Piaget, learning results from interaction with the environment lead to new learning experiences [7][11]. In [12], another study is presented. Authors report the benefits of the Internet of things (IoT) adoption in education, including increased interactivity, personalized learning, efficient classroom management, and better student monitoring. In [13], the integration of computer vision in tandem with IoT in education is also discussed.

The importance of Science, Technology Engineering, and Mathematics (STEM) and, therefore, educational robotics as a core part of it has been identified as a key tool towards digitizing education, involving students in learning activities, and developing their skills project-based learning through robotics. In this context, in recent years, many research programs have emerged related to educational robotics. Among them, the ‘Educational Robotics for ER4STEM (STEM)’ which has a concept the three important pillars of constructionism: (i) engaging students with powerful ideas, (ii) building on personal interests, and (iii) learning through making (or presenting ideas with tangible artifacts). Edubots is an ongoing Erasmus+ Knowledge Alliance project aiming to improve results and raise attainment levels in European higher education. The ‘Science with robotics’ project is another Erasmus+ Knowledge Alliance project which provides teachers with the necessary training to go one step further and introduce robotics to work with content from different areas. The CODESKILLS4ROBOTICS project, also funded by Erasmus+, aims to design an innovative program that aims to introduce coding and robotics’ to primary school students. The direct target group is children aged 9–12 years old, emphasizing children with fewer opportunities who will learn how to code. Furthermore, of course, these are just a small indicative sample of the research projects that have been funded and helped the evolution, adoption, and spread of educational robotics.

The increased importance of educational robotics for the academic and educational communities has been identified in [14]. The authors in [15] define the educational robotics term according to the three main fields involved: (1) education, (2) robotics, and (3) human–computer interaction and conclude that educational robotics ‘… is a field of study that aims to improve the learning experience of people through the creation, implementation, improvement, and validation of pedagogical activities, tools (e.g., guidelines and templates) and technologies, where robots play an active role, and pedagogical methods inform each decision…'.

The authors in [7] reassess the definition of educational robotics, using a bibliometric map, as an '… an essential branch of educational technology implemented by activities designed using the theory of constructionism focused on the development of computational thinking skills, collaborative learning, and project-based learning…'. Various definitions are also presented in [16][17]. In [16], educational robotics is described as a '… research field that aims to promote active engage learning through the artifacts students, create the phenomena and simulate…' while, in [17] educational robotics is defined as '…the application of robots and robotics activities in teaching and learning…'.

According to the literature, there are various ways where educational robotics can be applied in the learning process: (i) as a learning and teaching tool, during the pedagogical method or an educational practice where robotics are used as another I.C.T. tool in the hands of teachers; (ii) as a cognitive, educational object, where robotics is just another subject with its curriculum, and the student learns and understands among others the concept of robotics, the technical knowledge on how it works, how it is programmed and how it can be managed; (iii) as social robots where they interact naturally with humans and behave in a way that is comfortable for humans [15] and finally; (iv) as a valuable tool that can help students in developing cognitive and social skills during their K-12 education [18]. Independent of how educational robotics is integrated into the learning process, they aim to fulfill certain learning outcomes, as formally defined and outlined in [7]. These help to:

- Improve problem-solving skills by helping the student understand difficult concepts more easily, research, and conduct decisions.
- Increase self-efficacy: The machine's natural handling promotes experimentation, discovery, and rejection and, consequently, enhances the student's self-confidence because the student feels that he controls the machine. This also strengthens the students' critical thinking.
- Improve computational thinking: Students acquire algorithmic thinking to break down a large problem into smaller ones and then solve it. Students learn how to focus on important information and reject irrelevant ones.
- Increase creativity by learning with play-transmitting knowledge in a more playful form. Learning turns into a fun activity and becomes more attractive and interesting for the student.
- Increase motivation as educational robotics enables students to engage and persist at a particular activity.
- Improve collaboration as the team spirit and the cooperation between the students are promoted.

2. Computer Vision Meets Educational Robotics

Computer vision-related tasks in educational robotics demonstrate high potential in teaching assistance. Children's gain in learning is significant as determined by the selected articles' outcomes analysis. In the comparison groups, it was found that in those who were assisted with the computer vision procedures, the participants demonstrated more interest in the educational process, learned the concepts they taught more easily, spent less time completing their work, and generally were very satisfied with the way of teaching. The results highlighted that the most common use of computer vision in educational robotics is as a primary factor for teaching while, a limited number of studies (only 3) presented computer vision as an assistive tool only. Regarding the discussion in all relevant articles, the results were positive about computer vision tasks' effectiveness to support the learning process. The research claimed the increase in academic achievement from pre-school to secondary schools and special education in different subjects area and skills.

Moreover, through relevant articles, computer vision correlation with the six expected learning outcomes of educational robotics was presented, and the results are summed up in Table 1. It is noteworthy that 'Creativity', 'Motivation', and 'Problem-Solving Skills' are considered the most common learning outcomes supported by computer vision activities involving educational robotics, with 'Self-Efficacy' and 'Computational Thinking' to follow. The 'Collaboration' learning outcome appears with two degrees of participation; the articles' analysis has shown that the interactive game's use in the learning process involves all students to cooperate and develop a team spirit to succeed in a mission or to win. Future research directions in this area are needed to create an educational process that supports this outcome. One example of this direction is computer vision analysis of students' behavior and interaction during group tasks on how they communicate, teach others, and how comfortable they are with fellow students. Later, it enhances peer-to-peer interaction between students as per their comfort levels.

Besides, computer vision integration in schools depends on the robot model's availability and the cost factor. From the relevant article's analysis, we found that all the robot models presented in this study can easily enhance the educational process, and they are available for K-12 education. However, 60% of the documents used the humanoid and social NAO robot, recognizing its many potentials, without considering the high integration cost.

To sum up, computer vision-related tasks in educational robotics are considered useful tools for the learning process. The convergence of computer vision and educational robotics is still in the incipient phase. It is worth exploring ways in which such technology can mutually benefit the students involved in the education process to develop the proposed outcomes skills by making learning more effective, garner more attention from them, maximize their interest, customizing courses and materials as per their understanding capabilities, and most importantly, fun.

According to the different perspective observed by the systematic analysis, the essential factors that influence educational robotics enhanced with computer vision tasks in K-12 education effectiveness, include usability and availability of appropriate learning activities and content (knowledge area to be explored), children age group, robot models to be used and cost parameter. Possible applications to be designed must consider the robot as communication mediators to support group learning, interacting with the robot in a playful environment, the children can respond with high motivational levels and creativity, focus on children interests and weakness could improve self-efficacy, and helps to problem-solving and computational thinking skills. Further researchers would help develop more applications (design new or modify current robotic activities) to use computer vision in educational robotics.

Table 1. Correlating the expected learning outcomes of educational robotics with computer vision.

	Problem Solving Skills	Self Efficacy	Computat. Thinking	Creativity	Motivation	Collaborat.
Altin et al. (2014)		•			•	
Wu et al. (2019)		•			•	
Madhyastha (2016)					•	
Kusumota et al. (2018)				•		
Rios et al. (2017)					•	
He et al. (2017)				•		
Amanatiadis et al. (2017)		•				
Amanatiadis et al. (2020)		•				•
Jimenez et al. (2019)	•					
Olvera et al. (2018)	•			•		
Darrah et al. (2018)	•		•			
Kaburlasos et al. (2018)				•		
Efthymiou et al. (2020)				•		•

	Problem Solving Skills	Self Efficacy	Computat. Thinking	Creativity	Motivation	Collaborat.
Vrochidou et al. (2018)			•			
Majgaard et al. (2015)		•				
Alemi et al. (2014)	•			•	•	
Tozadore et al. (2017)				•		
Karalekas et al. (2020)	•				•	
Evripidou et al. (2021)	•	•	•		•	
Vega et al. (2018)	•					
Park and Lenskiy (2014)			•	•	•	

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