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Editorial

Recent Advances in Educational Robotics

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Abstract: The widespread use of artificial intelligence and robotics contributes, among other things, to create a new scientific field that aims to modernize and disrupt education. The term 'educational robotics' is being introduced as a learning tool and definitively transforming young people's education. At the same time, however, it is helping to create a fast-growing new industry that produces educational robots and tools. Companies with a long tradition, either in the creation of robotic equipment or in the production and distribution of toys, are setting up appropriate divisions and supplying the market with electronic devices for educational robotics. This new market is overgrowing and is rapidly becoming an investment attraction. According to MarketsandMarkets research, the educational robotics market is projected to grow from USD 1.3 billion in 2021 to USD 2.6 billion by 2026. Notably, the educational robotics market is expected to grow at a Compound Annual Growth Rate (CAGR) of 16.1% from 2021 to 2026. At the same time, however, the field is attracting many startups securing independent funding for equipment design and implementation and independent efforts competing for funding from crowdfunding platforms. More than 2000 ideas have recently secured funding to build and distribute educational robotics tools through Kickstarter-type platforms. However, what is educational robotics, and how is it expected to transform how the next generation is educated?

Keywords: educational robotics; computer vision; educational tool

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1. Introduction

Although the term educational robotics has been introduced into our everyday life in recent years, the research and development of tools dating back to 1969, Seymour Papert was the first to design and implement the Turtle robot, which allows students, by programming in Logo programming language, to move it. His effort is recorded as the maiden attempt at an alternative way of teaching algorithmic thinking and programming. At the same time, however, it is also a source of inspiration for the toy manufacturer Lego. With the expiry of the patent rights on the blocks that are the building blocks for the development of its products, Lego is in a difficult financial situation and is looking for alternatives. The Turtle robot forms the foundation for the company's new product, dynamic and programmable blocks. Lego introduces a product to the market that provides consumers with the possibility of programming in addition to the traditional option of building. Static constructions that helped develop many skills are evolving into animated units. Children, through play, are taught programming principles, expanding their knowledge base with skills that are likely to become the cornerstone of the demands of the modern age. At the same time, however, the market is welcoming a new product, and the commercial use of the term educational robotics is becoming widely known. In the years that followed, many companies presented similar solutions, developing the subject in a multidimensional way. Companies such as Robolink, Hanson Robotics, Modular Robotics, Primo Toys, and Engino develop excellent tools that transform the way of teaching. At the same time, research institutions and universities, with scientists from different research fields (computer science, engineering, psychology, and teaching sciences), are joining forces and presenting teaching methods and techniques that target specific expected educational outcomes.

Given the increased interest of researchers [1] and considering the new findings in the field [2,3], we found it valuable to design a Special Issue on recent advances in educational robotics. The subject of educational robotics focuses on the intersection of robotics and the education sciences. Unfortunately, the absence in the literature of journals focused on this field limits researchers from publishing their work. Therefore, the Special Issue published 12 papers, of which 4 were review articles. By observing the articles, one can easily observe that the Special Issue involves five academic institutions from Greece, four from Spain, three from Taiwan, two from Norway, one from Cyprus, one from Ecuador, and one from Chile. (kindly refer to Figure 1) The following section analyses the findings from these articles.

Figure 1. Geographical distribution of academic institutions participating in the Special Issue.

2. Analysis of the Articles

Toma et al. [4] developed a virtual unmanned aerial vehicle control training system in their work. It uses the mathematical models of kinematics and dynamics to visualize the behavior of uncrewed aerial vehicles. The new system can be used for educational processes without purchasing a physical robot. Furthermore, researchers proved the stability and robustness of the controller by implementing the advanced control algorithm for autonomous trajectory tracking tasks, both in the virtual training system and in the test performed experimentally with the hexacopter.

In another work [5], researchers introduce FOSSBot, a new educational solution that can cover multiple learning needs and can be adopted by different ages and programming skill levels. The proposed robot is 3D-printable and features a flexible software stack that supports four operating modes, such as block-based or text-based programming. The paper provides a detailed list of electronics and printable parts and their assembly instructions. The open nature of FOSSBot makes it a unique tool for educators who can teach several subjects, such as programming, sciences, and arts, at all educational levels.

A new robotic platform suitable for research and education in cooperative robotics is also presented in Kassawat et al. work [6]. The researchers introduce a novel concept for cooperatively lifting, manipulating, and transporting an object through the new robot platform. The proposed robot consists of three omnidirectional wheels with two additional traction wheels, making multi-robot object manipulation possible. To validate the new system, researchers conducted three experiments using a setup with one robot and one target object.

Using the Arduino platform, Cano, in her recent work [7], developed a methodological approach for teaching STEM skills with a genre focus. The proposed method includes a learning model called 5E (Engage, Explore, Explain, Elaborate, and Evaluate). It aimed to design a set of workshops for introducing concepts in electronics and programming.

Researchers conducted workshops in virtual mode through the Zoom platform with teachers from Latin American schools. It was confirmed that Arduino, its components, and the workshop increase students' creativity, attitude, and motivation.

El-Fakdi et al. in [8] present an educational robotics project specially designed for university students. Participants can create an underwater device using low-cost materials based on the proposed project. The Underwater Robotics Workshop project has been held for more than 13 years at the University of Girona, explaining the research in underwater robotics that is carried out there. The project aimed to promote physics, engineering, electronics, programming, and robotics. The authors presented positive feedback from participating students and teachers as concerned about students' satisfaction and learning objectives.

Another educational system driven by the need for low-cost solutions is proposed in [9]. The proposed method is called HYDRA and addresses elementary and secondary educational needs. The new system provides an expandable, modular design of low complexity for students without previous experience in programming and robotics. However, its most important feature is its slight learning curve. The researchers evaluated HYDRA using flow theory in three different grades of a Greek elementary school and found a high adoption rate among the participants.

A different use of educational robotics is presented in Ziouzios et al. [10] work. More precisely, researchers aimed to measure the development of children's empathy through the proposed educational scenario. In this project, a robot gives the students a message from the future, warning them about climate change and encouraging them to change their thinking and attitudes. A pilot study including 50 students in a sixth-grade class proved that the development of children's empathy and the effectiveness of programming on the robot were complemented and enriched with the pre-existing knowledge of teachers. Moreover, using a robot to convey the message increased students' interest and participation.

As concerns humanoid robots, Mishra et al. [11] proposed a multidisciplinary framework for using humanoid robots in an educational environment. The proposed framework has four aspects: technological, pedagogical, the efficacy of humanoid robots, and a consideration of the ethical implications of using humanoid robots. Moreover, the authors proposed a way to apply and evaluate the framework and a case study. Lin et al. [12] conducted a systematic review of 22 empirical studies published between 2010 and 2020 to study their interactive designs of oral tasks by evaluating the teaching methods, the types of oral tasks, the role played by the robots and the facilitators, and their effectiveness as a tool for improving oral competence. Researchers concluded that robot-assisted language learning instructional design employs communicative language teaching and storytelling as the most dominant language learning methods, and audiolingual and total physical response methods often complement these two methods.

The use of humanoid robots in special education is described by Papacostas et al. [13] in a systematic review of the period 2008 to 2020. The research focused on the investigation of the degree of integration of social robots in the training of special education individuals, the assessment of the scope of application of social robots in different impairments, the search for different types of social robots and their appropriateness by category of impairments and the emergence of challenges that need to be addressed for social robots to make a significant contribution to the social integration of people with impairments. The review presented various robots that target very different skills and children with diverse special education needs. However, it is pointed out that most of them were designed for something other than the specific needs of special education individuals.

Sophokleous et al. [14], in their review, focused on the studies that show how computer vision supports educational robotics. Using a systematic mapping process, they analyzed 21 primary articles from the recent literature. More precisely, they investigated computer vision's role, benefits, and efficiency in educational robots in K-12 education. The study showed that computer vision in educational robots has a high potential for teaching assistance. It is also shown that students' interest and satisfaction increase when computer vision is used in educational robotics projects. At the same time, they learn the concepts they are taught more efficiently and complete their work in less time.

Finally, Belmonte et al. [15] analyzed 926 scientific papers related to the "robotics" concept in the educational field from the Web of Science database. The authors discussed several topics: educational research, education of scientific disciplines, engineering, interdisciplinary computer science, and applications. More than half of investigated papers appeared in conference proceedings. Based on the focus of the scientific publication, this work found three different periods: in 1975–2012, physics engineering issues of robots, and basic concepts of education were the most prominent subjects; in 2013–2016, the most important topics were "programming" and "computational thinking" and in 2017–2019 subjects such as technologies supporting training and simulation techniques were the most discussed topics.

3. Conclusions

Conversely, educational robotics is a powerful and flexible learning tool that supports learners and instructors in many learning environments. Educational robotics is primarily suitable for teaching science, mathematics, technology, and computing. However, it can also be applied to other fields, such as literature, theatre, and the arts. As an educational tool, the robot can offer practical yet fun activities. It helps to create an enjoyable and participatory environment that keeps students interested and engaged. In addition, the play aspect involved in robots is an essential factor of positive motivation. Through hands-on robotics activities, students cease to be passive recipients of knowledge and take an active role. The activities allow them to deepen and 'master' more meaningful knowledge about their study subjects. In addition to acquiring new knowledge, the hands-on involvement offered by robotics has been shown to lead to the development and improvement of skills needed in the 21st century, such as problem-solving, critical thinking, and cooperation.

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