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(Review Article)

The perspective of STEM education through the usage of Robotics

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Abstract

Educational robotics is a transformative tool for learning, computational thinking, coding, and engineering, all of which are increasingly seen as essential components of STEM curriculum in schools. Although robots in education for school-age children has been around since the late 1900s and is becoming more popular among young pupils, it is not fully incorporated as a technology learning aid in traditional classroom settings. Numerous studies have recommended numerous hands-on robotics activities based on constructivist ideas, promoting the formation of knowledge based on reality for scientific and non-scientific stakeholders. Robotics may become an important focal point within technology provision, which is an important underlying attribute for the seminal development of computational thinking (CT). Despite the potential value of CT in strengthening a person's problem-solving skills, ways for improving this capacity through hands-on robotics activities are little unexplored. The purpose of this paper is to emphasize the relevance of incorporating educational robotics as a technological learning tool into regular curriculum for students and to show how it helps students prepare for the future.

Keywords: Educational Robotics; Computational Thinking; Coding; STEM; engineering

1. Introduction

The realization of the desire to educate a scientifically literate public has taken a long time, with science being included on the educational curriculum at all levels, including early childhood (Fernandes, Pires et al., 2016). Traditional science education, however, has not been efficient enough to fulfill that wish, and there has been a consensus for several years regarding the urgent need for the development of new strategies capable of training people in the languages of science and technology, so that young people can make informed decisions about their career options (Kefalis and Drigas, 2019). Thus, constructivist methodologies have been proposed (NAS, 1995), leaving aside traditional methods used in classroom praxis, which have been characterized by knowledge transmission, memorization, and the repetition of scientific content, without taking into account pupils' preconceptions and inappropriate practices for learning new skills and knowledge. This practice inhibits meaningful learning and the building of links between prior experiences and new knowledge rooted in the actual world, reducing instruction to a set of laws, ideas, facts, and notions. It is a style of teaching that emphasizes the teacher's protagonism and the learner's passive position (Drigas and Karyotaki, 2019), which appears to result in pupil failure in scientific topics and rejection in some cases. Based on these ideas, it is advocated that certain instructional designs be abandoned in favor of others aimed at promoting scientific activities that drive teachers and students to collaborate in order to gain new abilities (Lytra and Drigas, 2021).

. Integrated STEM emerges in response to the need for this methodological change, both to incentivize scientific literacy and to increase interest in scientific and technological areas, assisting students with the resolution of daily problems within their social network, and responding to the challenges of scientific and technological education. Many STEM programs have been developed in extracurricular hours and for students in compulsory secondary education (Bravou et al., 2022), but there have been few empirical studies that show how teachers can implement STEM programs within

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the school curriculum, particularly at early stages such as early childhood education (ECE) and primary education. These stages are well suited to the structure of schools, within which teachers can build interdisciplinary projects with greater ease, because this is the time when children show increased interest in scientific issues (Toma et al., 2017).

2. Theoretical Approach

Integrated STEM education is a strategy that integrates the subjects that make up the acronym (science, technology, engineering, and mathematics). It has created a new path for the teaching and learning of those disciplines (Martín-Páez, Aguilera, et al., 2019), pursuing the integration and cohesive growth of scientific and technical material within an interdisciplinary framework. This is done so that central scientific ideas can be examined with experimental components, using a more or less extensive integration of knowledge derived from the disciplines that comprise its acronym (Ortiz-Revilla et al., 2020). Its goal is to promote integrated education from a young age.

Integrated STEM education focuses on solving real-world problems through investigation and creativity in a way that engages students (Chaidi et al., 2022). It assists individuals in becoming responsible and autonomous participants of their own learning, developing the required competencies for advancement and coexistence within society, and improving self-efficacy in STEM fields and talent development. It thus necessitates the employment of certain didactic approaches, such as inquiry-based learning, engineering design methodology, and instructional coding and robotics for computational thinking (Bers, 2018). All of these techniques are student-centered, begin and circle around real-world problems, foster collaborative learning based on research, and incorporate hands-on activities (experiments as well as gadget creation) and promote the development of critical thinking, creativity, and self-directed learning. All of them are employed as tools to enhance scientific learning and are capable of greatly improving learners' competences and skills by increasing both their interest and motivation (Drigas, Mitsea and Skianis, 2022).

The effective application of integrated STEM education with an integrative perspective implies a challenge for teachers, because the teacher must be a guide in the development of scientific skills and competencies, which in turn strengthen significative learning, seeking a connection between science and pupils (Margot and Kettler, 2019). Despite this, incorrect teacher conceptions and practices regarding science and its nature have emerged in investigations, which result from distorted, ingenuous, and inadequate views (Demertzi et al., 2018). As a result, notwithstanding the efforts made thus far, the road ahead remains lengthy.

If the goal is to implement this approach in the classroom, teacher training may be proposed as a useful process that can renovate both the practice and ideas of traditional teaching that theoretical components promote for successful science teaching , moving toward teaching methods more akin to integrated STEM education. Canal, (Canal, 2007) originated with the idea that teachers must orient, develop, and reflect on the teaching-learning process not just from the perspective of the teacher, but also from the standpoint of the students, in order to satisfy their quest for knowledge (Chaidi, Kefalis et al., 2021).

Regarding the STEM approach, various research projects have concurred on the need for teachers who are involved, have solid knowledge and experience of the disciplines that the approach covers, and are capable of understanding their methods in order to introduce them into the classroom (Mitsea, Lytra et al., 2020). In STEM-integrated approaches, the teacher must encourage creativity through projects and critical thinking, with the ultimate goal of the students fixing the given challenges. Nonetheless, a study of the literature (García-Carrillo, 2019) reveals the problems teachers have in doing so, which are fundamentally linked to three factors: the training received; beliefs and attitudes; and teaching practice.

There are flaws in both didactic training and teachers' scientific understanding that can be missing on the ground and inappropriate when it comes to implementing STEM techniques. Some studies have found that teachers' negative attitudes toward science educational reform are caused by their superficial and fragmented conceptual and procedural knowledge, a lack of sufficient knowledge on scientific content , and a lack of personal and professional experience and practice in knowing how these contents are best applied in the classroom (Stavridis et al., 2017). As a result, teachers may have an incorrect view of science, technology, and engineering, as well as the contents and practices that must be addressed in these areas, resulting in the construction of incoherent, shaky, and ineffective notions for the growth of their professional labors. On the other hand, an outstanding feature of the training courses and professional development of teachers imparting scientific content in primary education is that they frequently oscillate between pedagogic and even psychological preparation, leaving area-specific content to one side, or they may only be centered on scientific content, of which almost all is directed toward teachers with a scientific training (Stavridis, Falco et al., 2020).

In terms of teacher beliefs and attitudes, the negative response to the use of more active teaching and learning methods can be explained by their lack of practice with these methods while teaching the subject matter. Similarly, they found the approaches to be slow and rarely viable (Drigas and Karyotaki, 2019), and on occasion, a lack of faith in the procedures among students meant that they could not work with them. Difficulties with teaching practice arise as a result of a lack of both resources and knowledge for the development of the inquiry-based method, a lack of time as a result of an overly extended curriculum, and the difficulties associated with the organization, economic costs, and dedication of this type of approach (Demertzi, Voukelatos et al., 2018).

As a result, certain training activities are required. The outcomes of one of these actions, the BotSTEM project, financed by the European Commission, are presented in this paper. The goal of this project is to provide new didactic tools and activities to introduce integrated STEM proposals for educational coding and robotics using novel methodologies. Although this training action will be explained further, it is emphasized here as training "in practice."

3. The Impact of Gender and Age on STEM Education

Age and gender are the most likely elements that influence user preferences in novel learning contexts, according to studies on children and adults (Sullivan and Bers, 2013). On the one hand, age is associated with acquired knowledge and experience with technology, and so appears to be a factor associated with user preferences and attitudes toward learning and robotics. Younger children appear to be less exposed to technology, but older children appear to be more familiar with technology and computers (Kastritsi et al., 2019). As a result, it appears that different tools and interfaces are required to better support the learning process for various age groups. Thus, it appears that different tools and interfaces are required to better support the learning process for various age groups. For example, tactile user interfaces appear to be highly promising for young children, owing to their ability to lower the age requirement for involvement in ER and programming activities (Sapounidis and Demetriadis, 2013).

Although there are a few studies exploring the benefits of various technologies in ER, there is a scarcity of study into mixed technologies and hybrid systems. Such systems may mix, for example, diverse interfaces (graphical - physical) and technologies (e.g., open-source hardware/software) in a single platform. Adoption of mixed technologies and hybrid systems, in which different age groups do not need to learn to utilize more than one system to suit their educational needs in the ER, may lessen users' cognitive load. This is because studying the subject matter and simultaneously learning how to use a new technology are processes that employ the same cognitive resources (Baddeley, 2017). Gender, on the other hand, is another element that may influence inclination, attitude, and preferences for learning with technology. According to the social psychology literature, both genders have different preferences and behavior in pair and group activities as well as different attitudes and motivations (Ntaountaki, Lorentzou, et al., 2019).

Specifically, researches on technology have revealed that, while guys appear to be more self-confident, girls are more likely to struggle with ER and programming skills. Furthermore, girls exhibit a stronger preference for tactile user interfaces. The reason for this is that boys play computer games more than girls, therefore girls are less familiar with computer technologies and graphical user interfaces. Girls prefer games with more social interaction, according to studies focusing specifically on games (Drigas and Sideraki, 2021), which may be better supported by certain technologies such as tangible user interfaces . Interestingly, as women age, their attitudes and inclinations toward technology and computers become less positive due to the influence of gender and cultural stereotypes (Sullivan and Bers, 2013).

As a result, it is expected that the earlier children become aware of technology, the less gender-related preconceptions they would develop (Ntaountaki, Lorentzou, et al., 2019). As a result, incorporating ER and programming at a young age may help to prevent the creation of unfavorable gender stereotypes. In any event, research on gender effects in programming and ER is fairly limited because these domains are relatively new, particularly in early infancy (Sapounidis, Theodosios et al., 2019).

4. Educational Robotics

Educational robotics (ER) is a subfield of robotics that provides students with learning experiences through the invention and deployment of robot-related activities, technologies, and artifacts (Angel-Fernandez and Vincze, 2018). Seymour Papert invented the Logo project (Papert, 1972), a mobile robot in the shape of a turtle to teach programming to youngsters. The turtle could be programmed to write pictures on the surface on which it moved with a pen located in the bottom center of the robot.

Educational robotics has mostly supported the teaching of courses closely related to the robotics sector, such as programming, building, and mechatronics. However, the studies discovered have used the robot as a passive tool in which students must program the robot. Students who are not interested in traditional ways get inspired when robotics activities are introduced as a tool to tell a story or in combination with other disciplines and interest areas Rush (Moraiti, Fotoglou and Drigas, 2022). According to an American Association of University Women report, "girls and other nontraditional users of computer science--who are not enamored of technology for the sake of technology--may be far more interested in using technology if they encounter it in the context of a discipline that interests them."

As a result, robotics construction kits can be utilized in a variety of ways to support a wide range of activities and learning styles. Plaza et al., 2018 employed the Arduino embedded system as an instructional tool to introduce robotics, in which youngsters built and developed tangible prototypes for problem-solving. PicoCricket is a robotics kit that tries to mix art and technology, allowing young people to make beautiful masterpieces. PicoCricket has output devices such as motors, colored lights, music-making devices, and sensors. In 2019, Xenabis et al., used recyclable materials and programming with Arduino UNO to build the Wall-E robot and program it using an Ardublock platform.

Four requirements were addressed when designing the robotics kit: low cost, attractiveness, simplicity, and open source. They employed block programming dubbed a tiny block for the programming environment. The following eight learning modules were prepared for use with this kit: (1) What are we going to learn? (2) What is robotics? (3) What is Arduino? (4) Learning to program with Minibloq; (5) Electronic components; (6) What are sensors? (7) Robot architecture; and (8) Robot operation. At the end of the course, they posed related questions regarding whether the kit was a good option for understanding electronics and programming topics.

Educational robotics has also been linked to computational thinking and STEM learning. Educational robotics is now being used in classrooms as a type of teaching-learning that can aid in the development of competences and encourage learning in fields such as engineering, technology, mathematics, and science. Several studies (Charoula A. and Nikos V., 2020) have found that instructional robotics has a favorable impact in STEM fields by promoting a grasp of STEM-related concepts. ER can be useful in STEM education because it allows students to interact with real-world engineering and technology topics.

ER is now being used in schools as an alternative to empower students in diverse fields such as engineering, physics, and mathematics (Jurado et al., 2020). Teachers have begun to devise activities to bring robotics into the classroom. Individual initiatives, on the other hand, are more numerous. Additionally, "robotics has the potential to significantly influence the nature of science and engineering education at all levels." As a result, educational robots began to be utilized in robotics contests to stimulate learning. These challenges also use goal-oriented and project-based learning (PBL), and they are mostly directed toward the engineering, computer science, and artificial intelligence sectors.

ER is associated with cognitive skills, the scientific method, problem-solving approaches, and teamwork skills. Alves-Oliveira's study includes activities that foster creativity in children. They engaged in three activities for this study. The initial task was to program the robots. The second activity condition featured learning to create robots, while the third activity condition involved a music lesson. They learned to utilize the Scratch programming language in the first activity of this study.

5. ER Teaching Methodologies

The term instructional robotics is frequently used in classrooms. There is currently no agreement on how educational robots should be taught, particularly from a gender standpoint. Some learning approaches have been offered, whose major goal is to understand how to bring the concepts of robotics and associated themes into the student curriculum (Patiño-Escarcina et al., 2021). The authors concentrate on topics like as physics, electronics, control, and computers. They suggest a three-phase methodology: (1) Setting up the environment in which a problem is identified and themes are chosen; (2) project definition, in which concepts and strategies are produced; and (3) evaluation, in which theoretical concepts are implemented and competences are assessed. They include four variables in the evaluation of competencies: communication, teamwork, creativity-responsibility, and integration of STEM topics. Activities incorporating educational robots function through collaboration and teamwork (Bamicha and Drigas, 2022).

O de Azevedo et al., 2017 presented a contextualized ER methodology in which work begins with a diagnosis in the school, with the children, and in their community. The process is broken down into five steps: initial diagnosis, survey of contextualized problems, course development, classes, and a robotics fair. Although the methodology was proposed, it was not tested. Another study (Chaidi et al., 2022) presented a seven-phase technique. The teacher follows a predetermined structure during the first two phases, with the primary goal of explaining theoretical principles and training pupils in software. The learning process is required for all other phases, therefore the instructor serves as a coach and cognitive modeler.

Three tactics lead to inventive solutions in robotics tasks: give a new function (the students identify a new application for the robot); remove a component from the system; and analyze physical objects accessible in the environment and apply them to solve a problem. Several studies have shown that educational robotics has a favorable impact on the development of skills such as critical thinking (Doleck et al., 2017), problem solving (Stavridis and Doulgeri, 2018), metacognitive skills, and creativity. More research is needed in educational robots to determine how to work with educational robotics to improve abilities in kids, as these skills have also not been well examined. Meanwhile, Sullivan discovered that during the various steps of programming a robot, students (1) write code, (2) test the robot, (3) assess the problem, (4) propose improvements to the model, and (5) test again. As a result, the author outlines three steps in problem resolution: (1) identification of the problem, (2) creation of ideas and strategy selection, and (3) reflection on the process of problem resolution.

Atmatzidou and Demetriadis, conducted 11 robotics training sessions for public school kids. They presented a model for developing computational thinking skills within educational robotics. The authors concentrated on five dimensions of the conceptual framework of computational thinking: abstraction, generalization, algorithm, modularity, and decomposition. They used the Lego Mindstorms NXT robot kit as a tool. The papers show that there is no dearth of research on educational robotics. However, robotics instruction in schools is still in its early stages (Chaidi et al., 2022). More study on how to work with educational robotics for teachers in order to assist pupils develop certain abilities is thus required. Project-based learning, problem-based learning, active learning, collaborative learning, experiential learning, and fun learning are the approaches linked with the term map. Constructivism and constructionism are related with all of these methods.

Many teachers are still unaware of the benefits of educational robotics and are unprepared to teach robotics or ideas related educational robotics, such as electronics, programming, and technology. As a result, there is a paucity of specialized training programs for educational institutions centered on instructors, because the majority of researches identified are focused on the student rather than the teacher. Some studies include ICT teachers as participants, while others include STEM subject teachers (Stavridis and Doulgeri, 2018). In 2021, (Schina, 2021) conducted a survey of the literature on teacher preparation in educational robotics. The authors discovered that participants in the training programs come from a variety of backgrounds, including teaching experience, age, familiarity with technology, and so on. Furthermore, many ER trainings give training programs with no requirements, and those who study programs with requirements have a final project of designing a robot, producing a program, or designing didactic material. Despite the fact that the majority of the teachers that enroll have a background in electronics or programming, many of the studies focus on developing a robot.

6. The Role of Robotics as a Hands-on Media Facilitating Active Learning Experience

Integration and use of educational robotics in the teaching-learning process at the pre-school, primary, and secondary levels can become visible and be a turning point as a resource for addressing classroom diversity as well as keeping students actively engaged and motivated (Daher, 2022). Active learning is defined as a technique of instruction that encourages students to become actively engaged with course material through conversations, problem solving, case studies, role plays, and other ways. While robotics is a hands-on learning platform, the combination of robotics and an active learning strategy is critical in generating synergy, and it is more effective when it is effectively synchronised (Drigas and Sideraki, 2021).

Unlike earlier research, this report emphasizes how educational robotics inspired pre-service teachers to actively participate in STEM learning. The research participants were actively participated in all activities, particularly during the exploration period. The activities closely related to robotics media allowed participants to explore various sources of knowledge. This concept supports Papert's (1976) argument that support supplied by learning activities will be more practical if students develop their own knowledge through a hands-on object relevant to that knowledge.

During the explanation phase, the participants actively articulated the problem-solving process in creative and imaginative ways. Participant 4 stated that the assembly would be more efficient if the robotics components were grouped together: 'At first, I got the components mixed up frequently. I believe it would be lot easier if the robots' pieces were organized by shape. We also need to imagine how the robot will move so that when we execute the software later, it moves correctly'. The robotics activities enabled participants to make important learning decisions and take responsibility for analyzing or determining the progress of their gained understanding. Furthermore, robotics media are usually sufficiently adaptable to relate to real-world challenges or issues (Jung & Won, 2018).

7. Robotics Activities develops links to Prior Life Experience

It is widely accepted that the hands-on characteristics of educational robotics provide learners of all ages with a real-life experience (Bamicha and Drigas, 2022). As a result, robotics allows students to use all of their senses when building, coding, and playing with robots. Robotics also offers learners with a topic for conversation and expands their awareness of the world.

While experience is a continuous process that includes an individual's previous experiences as well as new experiences, people's unique life experiences impact how they view and understand the world around them (Manikutty, 2021). According to the literature, the presence of prior experience influenced participants' decisions regarding how they carried out robotics tasks in STEM learning. This is because the participants continuously contrasted their existing experience with their newly formed understanding to select their course of action throughout the many STEM learning phases of this research. This study advances understanding by focusing on the nuances of the linkages between previous life experiences during each stage of STEM learning (Anagnostopoulou, Alexandropoulou et al., 2020).

During the engagement phase, the participants were exposed to enjoyable activities that blended the usage of robotics media with STEM instruction. They compared the learning ideas involved in building the robot to their previous knowledge. The complexity of the robotics activities in the learning process was assessed to be the difference. Furthermore, it boosted the participants' interest in terms of activating the initial motivation to do well in terms of the learning activities.

During the exploration phase, the participants addressed a variety of difficulties through a number of robotics-based exercises (Budiyanto et al., 2022). When given a task, they attempted to solve it. The mathematical content utilized in the study prompted the participants to recall their previous experiences or expertise. The participants' existing knowledge, in turn, assisted them in adjusting to the new learning environment. As a result, when participants encountered material-related challenges, they could suggest hypothetical solutions, as evidenced by Participant 2: 'I noticed a pattern among the presented issues, which is a difference in the angles with a three and four-fold repeat. I replicated the code for the programming block so that once I finished writing the steps for the solution and incorporating it into the programming block, I only needed to tweak the angles and repetition.'

When confronted with learning settings that they had either recently encountered or had never encountered before, the participants' thinking and behavior patterns shifted. During the evaluation phase, for example, participants noted a deficit in their programming abilities. However, at the end of the course, they had proved that both the research circuit and the robot were operating in accordance with the guidelines. More importantly, STEM learning using robotics presented learners with a novel experience. The experiences they had helped them adjust so that they could learn relevant knowledge and build relevant abilities. Any amount of experience that an individual goes through, no matter how big or tiny, can still become information that aids in their intellectual development (Ntaountaki, Lorentzou, et al., 2019).

8. Robotic Intervention Promotes Learning Scaffolding

Learning scaffolding aids in the delivery of technology-based courses. A scaffolding method is consistent with the concept of decomposition in CT (Angeli & Valanides, 2020;), particularly when it comes to utilizing educational robots as a modular learning aid. As previously stated in the literature, the robotics-based STEM learning in this study appears to have resulted in the development of deep understanding and meaningful knowledge due to its scaffolding (tiered) design. According to Angeli's research, the participants meticulously designed their robotics model and subsequent computer scripts to get the desired output. Participants noted that they scaffolded the learning of algorithmic thinking abilities from sequencing to debugging, produced the pseudocode and computer code, and lastly tested the software. In our case study, Participant 5 stated, '... I have done the programming for assignment number 1, so I can easily answer (assignment) number 2...'

Participants did not stop until they had either answered the task successfully or discovered no additional faults. This gave them the opportunity to expand their knowledge and skills in order to continue progressing, despite the fact that they only increased significantly from their former positions. During the elaboration phase, participants develop become self-sufficient individuals on their path to higher levels of knowledge and abilities. The researchers contend that the modularity of the Lego Mindstorm EV3 facilitates scaffolding learning. The comprehension of participants is gradually gained and can be maintained through trial-and-error activities in this approach. Any inaccuracies will be corrected as soon as possible by participants. Following that, the errors are reviewed to produce a report that can be utilized to solve the problems.

Robotics activities can give an alternative option for participants to gain long-term knowledge. The constructivist ideas are used in the learning phase. Robotics media, which can give activities connected with ordinary life, also employ constructivist concepts. As a result, Chu et al. (2019) said that STEM is structured with constructivist activities and supported by constructivist media in the learning process. This, in turn, can aid in the development of knowledge and skills. Furthermore, STEM learning with robotics allows individuals to be directly involved in scientific thinking, idea generation, and evidence collection.

9. Conclusion

The positive and useful contributions that digital technologies provide to the field of STEM education should be highlighted as a final point. Mobile devices (36-40), a range of ICT apps (41-57), AI & STEM ROBOTICS (58-73), and games (74-76) are some examples of the technologies that enable and improve educational processes including evaluation, intervention, and learning. Additionally, the use of ICTs in conjunction with theories and models of metacognition, mindfulness, meditation, and the development of emotional intelligence [77-112], accelerates and improves even more educational practices and outcomes, especially in STEM education domain.

More specifically the integrated STEM approach to instructional coding and robotics successfully encouraged educational innovation focusing on the science teaching-learning process. This approach promoted positive attitudes and interests among students and teachers, benefiting working habits, the teacher's knowledge of the students and their needs, cooperative work, and both significant and critical learning, and eliciting high levels of satisfaction among the professional teaching staff as well as learning among their students. Teachers and students should first become aware of the potential benefits of educational robots in motivating, engaging, and involving others. At the same time, teachers must understand how to use documentation effectively. In more detail: (a) educators, particularly Those without a technical background should learn to use the tools and available guidelines; (b) they should learn to use collaboration scripts to separate children into efficient groups in order to achieve the best learning outcomes; and (c) they should become aware of proper scaffolding methods in order to enable learners to progress faster without losing interest.

Robotics in education efficiently engages students in the learning of STEM concepts, coding, computational thinking, and engineering skills, all of which are required for students to become successful members of the workforce in the future. Educational robotics is an all-in-one technological learning tool that enhances our children' future success and should be integrated more and more into school curricula.

Compliance with ethical standards

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Disclosure of conflict of interest

The Authors proclaim no conflict of interest.

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