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# THE INFLUENCE OF EDUCATIONAL ROBOTICS IN STEM INTEGRATED LEARNING AND THE DEVELOPMENT OF COMPUTATIONAL THINKING ABILITIES

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**Abstract**

Currently, educational robotics are becoming an important trend in education, introducing transformative elements into the classroom to improve the learning environment. Educational robotics in STEM-integrated learning can develop computational thinking skills. Educational robotics has begun to be widely adopted and is expected to enhance computational thinking skills in early childhood education, secondary school, and higher education. In this study, we examine the role of educational robotics in integrated STEM learning environments and its impact on the development of computational thinking. The method used was a systematic literature review. Initial search returned 541 articles from various journals indexed in Scopus. Subsequently, 351 articles published between 2020 2024 were sorted out, and only 37 articles were included in the final analysis. Studies show that educational robotics effectively promotes STEM education and facilitates the development of computational thinking skills. The importance of project-based learning and the integration of STEM disciplines in educational robotics inform educators and policymakers about the potential benefits of educational robotics in promoting STEM education and developing computational thinking skills.

**Keywords:** computational thinking, educational robotics, STEM, systematic literature review

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## INTRODUCTION

In today's technological age, one of the abilities that must be mastered by students is computational thinking. Computational thinking became popular when it was introduced [1]. According to its description, CT is a method of thinking that involves both problem-solving and designing to understand human behavior by applying computer science principles. It also involves expressing the problem and its solution algorithmically so that a computer can solve it.

The main pillars of computational thinking are abstraction, decomposition, pattern recognition, and algorithm design. These four methods can be combined according to the problem to be solved. Computational thinking also has three main drivers: science, technology, and society[2]. Although the basis of computational thinking comes from computers, it can be applied to a number of problem solving[3]. Computational thinking is applying core computer science concepts to solve problems, develop systems, and comprehend human behavior[1]. When teaching fundamental abilities like reading, writing, and math, CT is frequently employed in classrooms[1]. But the incorporation of CT is not a topic within itself; rather, it is typically connected to robotics or technology. This can be attributed, in part, to the lack of progress in the CT discipline's dimensions or working principles. To address this computational concepts, practices, and perspectives are suggested as the three main components of a computational thinking framework by Brennan and Resnick [4].

One way to help students in mastering computational thinking skills is with a learning model, namely STEM, STEM is a learning model that combines, science, technology, engineering, and math. Because, every aspect of STEM (Science, Technology, Engineering, and Math) will help learners if integrated which is useful for solving problems much more comprehensively. Integrating all these aspects in learning makes the information more meaningful. While STEM education is demanding and hard to understand, it can assist the next generation of students utilize cross-disciplinary concepts, critical

thinking ability, teamwork, and creativity to address real-world problems[5].

STEM learning can be incorporated by utilizing educational robotics so that students can increasingly apply computational thinking. Robotics is a field that studies the design, construction, operation, and application of robots. Educational Robotics is an effective learning tool for project-based learning that integrates STEM, coding, computational thinking, and engineering skills into one project because robotics will give students the opportunity to explore how technology works in the real world [6]. Robotics can help pupils develop sophisticated thinking abilities and increase their capacity to solve challenging challenges in a cutting-edge learning environment. [7] Certain features of educational robotics have the potential to influence pedagogical outcomes across various disciplines, either directly or indirectly. Robots are planned and assembled physical objects. They include of electric circuits, motors for movement, tilt, position, and temperature sensors, as well as a hub connector that connects the robot to the computer[8]. Educational Robotics not only can help students develop Computational Thinking skills but also contributes to solving complex problems[9].

In an outstanding publication in Indonesia very little is discussed about educational robotics and also computational thinking but discusses about learning technology using: virtual reality[10], augmented reality[11], interactive learning media[12], etc.

The use of educational robotics for schoolchildren has actually been around for more than a decade, but in recent years the popular interest in robotics has grown surprisingly[13]. On K-12 usually robotics is an extracellular. Skills focused on learning robotics are fields of mathematics and physics[13].

Explains that two educational robotic systems that can help in developing computational thinking namely, Arduino and Lego EV3[14]. Arduino is a developmental platform for the creation of educational robotics projects and also one of the most widely used educational robotic systems. The LEGO EV3 is a product developed by the LEGO Group that is designed for education, STEM learning, and technological skills development.

According to Boya-Lara's study the robot that can also develop the students' computational thinking abilities is the BEAM robot through electrical, electronic, and mechanical lessons. Adopting robotics into education is great to do and will help students in developing the skills they need. However, there are some challenges to overcome, including costs, teacher training, and integration with existing curricula. With the right strategies and the necessary support, schools can successfully face these challenges and leverage the potential of robotics in STEM education[15].

Robotics has become a very important topic in learning computational thinking right now [16]. By problem solving, logic, algorithms, data analysis, modeling, cooperation, and other learning activities, educational robots can help students develop the computing skills necessary to meet the problems of the digital age. This can lead to even more critical thinking on the part of the students. Therefore, by using robotics in the classroom, teachers may help students learn and grow in a variety of computational thinking skills through hands-on activities and real-world applications.

Eucational robotics, according to Eguchi, is a useful tool for STEM-based learning since it combines engineering, computational thinking, and coding into a single project. Additionally, educational robotics can be used in other subjects besides STEM. Students can develop new collaboration strategies, problem solving techniques, and more critical and creative thinking through robotics education[17].

In Secondary schools in Barcelona, Spain, introduced instructional robotics and computational thinking. They aimed to increase knowledge in the fields of science, technology, engineering, the arts, and mathematics through the use of project-based learning. Students who utilized the block-based programming environment Scratch showed stronger progress in these concepts and abilities when compared to alternative teaching approaches, indicating that Scratch had a positive impact on STEM and CT learning[18].

## METHOD

In this research, a systematic literature review approach was used to perform an extensive evaluation of the present state of research on the integration of educational robotics in STEM learning and its impact on the development of computational thinking skills. The review was limited to publications that were listed in the Scopus database, guaranteeing a large and reliable collection of scholarly sources. The search for relevant material was carried out specifically using the terms "computational thinking," "educational robotics," and "STEM." Papers published between 2020 and 2024 were included in the review to guarantee the findings' applicability and timeliness. By taking a methodical approach, it was possible to identify and analyze current trends, insights, and knowledge gaps in the field, which has resulted

in a solid foundation for understanding educational robots' role in STEM education. The goal of the systematic literature review was to compile the results of these studies and provide a thorough picture of the ways in which educational robots might be successfully incorporated into STEM courses to improve students' computational thinking skills.

The literature gathered for this study serves to address two primary research questions: (1) What is the most effective way to integrate educational robotics into STEM learning? (2) How can educational robotics be used to develop computational thinking?.

Asserts that a comprehensive analysis of the use of articles is important for a systematic literature review and that this analysis entails abstracting the relevant data using a matrix idea [9]. This rigorous methodology guarantees the thoroughness of the evaluation and the conclusions generated from a solid analysis of the material that is currently available. the study is able to present a thorough summary of the results, emphasizing the best approaches for incorporating educational robotics into STEM education and its function in fostering computational thinking abilities.

The Systematic literature review approach is applied in this article. Scopus are used in this study. These papers, which were compiled using the keywords ``educational robotics", "computational thinking," and "STEM " were published between 2020 and 2024.

The use of matrix concepts is considered essential to conduct a thorough analysis of the article and ensure the extraction of information relevant to the examination[9]. Furthermore, it is clear that the focus of literature was on how educational robotics can help build CT capabilities in STEM learning, as shown in Table 1.

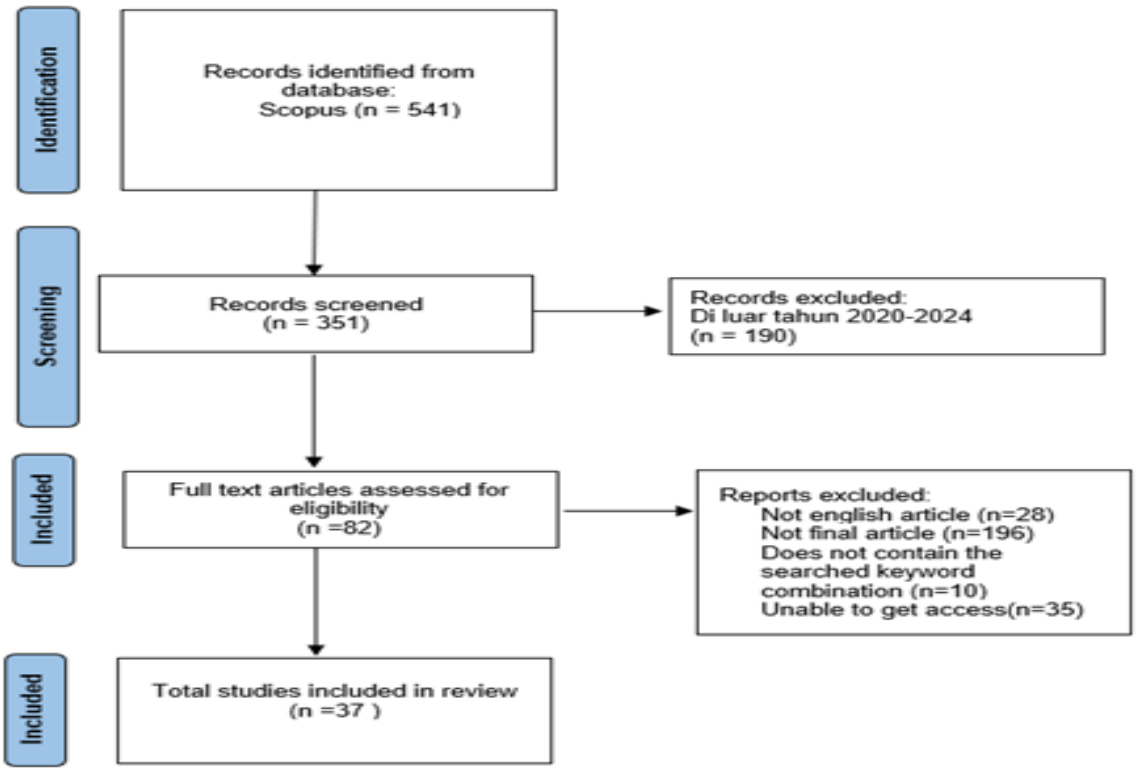


Figure 1. PRISMA Diagram

Table 1 Matrix concept of Educational robotics Contribution to CT Skills in STEM Learning

| Reference | Method | Participants | Finding(s) | RQ | Insight | Synthesize |
|---|---|---|---|---|---|---|
| Kerimbayev, N., Nurym, N., Akramova, A., & Abdykarimova, S. (2023). Educational Robotics: Development of computational thinking in collaborative online learning [Article]. Education and Information Technologies, 28(11), 14987-15009. https://doi.org/10.1007/s10639-023-11806-5 | Experiment | Students | This study demonstrates that integrating educational robotics into a collaborative online learning environment can enhance students' computational thinking skills, as evidenced by their improved programming, algorithmic thinking, and teamwork abilities. | 2 | Provides valuable insights into the advantages of using Educational Robotics for collaborative online learning in enhancing students' CT abilities. | Educational robotics impact |
| Budiyanto, C. W., Fenyvesi, K., Lathifah, A., & Yuana, R. A. (2022). Computational Thinking Development: Benefiting from Educational Robotics in STEM Teaching [Article]. European Journal of Educational Research, 11(4), 1997-2012. https://doi.org/10.12973/eu-jer.11.4.1997 | Case study | students | Hands-on robotics activities can be useful in developing problem-solving skills and strategies for individuals in STEM teaching and this research addresses the correlation between Computational Thinking (CT) principles and the STEM learning phase | 1 | robotics is very beneficial in STEM learning because it develops skills and problem-solving. | hands-on design and application |
| Boya-Lara, C., Saavedra, D., Fehrenbach, A., & Marquez-Araque, A. (2022). Development of a course based on BEAM robots to enhance STEM learning in electrical, electronic, and mechanical domains [Article]. International Journal of Educational Technology in Higher Education, 19(1), Article 7. https://doi.org/10.1186/s41239-021-00311-9 | design and implementation | students | The use of BEAM robotics in the context of STEM education can enhance knowledge and skills. This study succeeded in showing a significant improvement | 1 | Using BEAM robotics in STEM education effectively enhances engineering students' understanding and skills in | hands-on design and application |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | in student understanding | | electrical, electronic, and mechanical engineering. | |
| Pou, A. V., Canaleta, X., & Fonseca, D. (2022). Computational Thinking and Educational Robotics Integrated into Project-Based Learning [Article]. Sensors, 22(10), Article 3746. https://doi.org/10.3390/s22103746 | Project Based Learning | students | The study evaluated various aspects, including computational thinking and programming skills learned with the ScratchTM platform. It found improvements in concepts, practices, perspectives, and skills such as communication, creativity, collaboration, and community-building through project-based learning. | 2 | The effectiveness of integrating Project-Based Learning (PBL) with computational thinking and robotics education in enhancing student skills and understanding of computational concepts. | Teamwork and collaboration |
| Coufal, P. (2022). Project-Based STEM Learning Using Educational Robotics as the Development of Student Problem-Solving Competence [Article]. Mathematics, 10(23), Article 4618. https://doi.org/10.3390/math10234618 | experiment | students | According to the research, students who were taught programming through project-based learning using robotic kits performed better on problem-solving tests than students who were taught traditionally. This suggests that project-based learning utilizing educational robotics had a beneficial | 1 | The study offers valuable insights into how project-based learning with educational robotics enhances students' problem-solving skills. By comparing project-based learning outcomes with traditional | Teamwork and collaboration |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | effect on students' development of problem-solving abilities. | | teaching methods, it underscores the positive effects of hands-on, experiential learning in STEM education | |
| Cervera, N., Diago, P. D., Orcos, L., & Yáñez, D. F. (2020). The acquisition of computational thinking through mentoring: An exploratory study [Article]. Education Sciences, 10(8), 1-11, Article 202. https://doi.org/10.3390/educsci10080202 | Case study | students | Mentoring using educational robotics like Bee-bots can be an effective means of improving motivation and computational thinking skills in young students. | 2 | Introducing and developing computational thinking abilities in young children can be achieved through mentoring combined with educational robotics, such as using a bee bot. | Educational robotics impact |

## RESULT AND DISCUSSION

This study yielded numerous important discoveries based on the findings of the idea matrix-based analysis of the 37 articles that were used. This project, which will run from 2020 to 2024, aims to comprehend how instructional robotics affects students' ability to think computationally in STEM classrooms. The study tackles two main research topics by using a Systematic Literature Review (SLR) approach, carried out in compliance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines: (1) How might educational robotics be best incorporated into STEM education? and (2) How might computational thinking be fostered through educational robotics?

### Teamwork and Collaboration

Teamwork and collaboration are one way to enhance students' computational thinking skills, according to research, integrated STEM learning can improve group understanding and increase students' motivation to increase their confidence in doing something[19]. According to the study group collaboration will encourage peer-to-peer collaboration of students to improve students' understanding of technological concepts, computing thinking, and robotics education[18].

In addition, collaboration in the form of group work can also increase the motivation and involvement of students in learning. By working together toward clear goals, students feel more engaged and motivated to contribute actively to the learning process. Educational robotics has a greater influence on developing crucial 21st-century abilities, such as collaboration, creativity,

problem-solving, project management, and different forms of scaffolding that are useful[20]. Teamwork and collaboration among students in robotic educational activities play an important role in the development of computing thinking skills (CT). The concept of cooperation in an educational robotic environment enables students to learn in a team, share ideas, and work together to solve complex problems. It helps cultivate teamwork, communication, and joint problem-solving skills among students[21].

**Hands-On Design And Application**

Hands-on design and application indeed be integrated into STEM (Science, Technology, Engineering, and Mathematics) education. Numerous research papers and educational frameworks that highlight the value of experiential learning in the development of STEM skills and competencies support this combination. Hands-on robotics activities engage students actively, making abstract STEM concepts more concrete and understandable. This engagement helps in retaining information better and fosters a deeper understanding of STEM principles.

A hands on activity condition occurred during students engagement in BEAM robotics design, including robotic structure planning, component selection, and electronic system design [15]. Through these hands-on design and application activities, students can experience practical learning that is directly related to the STEM concepts they are learning. Hands-On Design And Application are shown in the learning module "Mighty Micro Controllers (MMC)" designed for students in classes 7 to 9. Students are introduced to the use of the Arduino Uno microcontroller as a tool for learning computational thinking in this module. They're trained to design and program microcontrollers to do certain things, like controlling LED lights or temperature sensors. Students not only gain an understanding of concepts of computational thinking, but they can also apply these concepts in hardware design and programming through the use of microcontrollers. This method allows students to have a hands-on experience of applying the ideas they learn. It improves their understanding of computational thinking [22].

Involving students in assembling and observing robots in executing orders given. Educational robotics activities provide an opportunity for learners to test their hypotheses, support problem-solving, and reasoning. In addition, robotic activity also provides sensory input that can help in the development of abstract concepts in pupils. Through this hands-on experience, students can develop computational thinking and related skills more concrete and interactive way [3].

**Educational Robotics Impact**

Integrating Educational robotics into the learning environment, especially when it comes to fostering student computer literacy, has a positive impact, as evidenced by several studies. Educational robotics can make students think even more critically because through problem-solving, logic, algorithms, data analysis, modeling, and collaboration, students can sharpen computing skills that are essential in facing the challenges of the digital age[16].

The integration of robots in the classroom has a profound effect on students' ability to think critically about science and mathematics. Robotics is regarded as a starting point for the study of applied mathematics, scientific inquiry, and problem-solving techniques. Robotics can also help pupils become more motivated and persistent in the face of difficult and complex learning situations. Consequently, education robots can help to improve STEM learning results in the K–12 setting[23].

Robotics has had some influences, among others: (1) Increasing interest and enthusiasm, the use of robots in learning activities succeeded in attracting the interest and enthusiasm of children in using and programming robots, as evidenced by the positive feedback received from them. (2) Development of computing skills: through interaction with robots, children can develop their computational thinking skills, including problem-solving, communication, reasoning, and problem-solving. (3) Additional motivation: the use of these robots can also increase the student's motivation to solve the problem, due to the students' affection for the robot. Thus, the use of robots not only provides a pleasant learning experience for children, but also helps in the development of computational thinking skills and learning motivation[24].

**CONCLUSION**

In conclusion, the integration of educational robotics into STEM learning and its impact on the development of computational thinking skills have been significant areas of interest in educational research, hands-on design and implementation is the most effective way to include educational robotics into STEM teaching. By allowing students to actively participate in robotics projects, this method helps make abstract STEM concepts more relatable and understandable. Engaging pupils in practical applications of scientific, technological, engineering, and mathematical concepts through hands-on activities facilitates experiential

learning. The integration of hands-on design in educational robotics facilitates: active engagement, interdisciplinary learning, problem-solving skills, and innovative thinking. Cooperative learning and teamwork are key components of computational thinking (CT) skills development through educational robotics. Collaborative robotics projects include important components such as collaborative, problem-solving, peer learning, communication and coordination, and real-world applications to help students' CT abilities to grow through teamwork, idea sharing, and problem solving. The impact of educational robotics prepares students for future challenges in both academic and professional lives by encouraging deeper understanding of STEM principles and improving computational thinking. This approach encourages a mindset of lifelong learning and adaptability, which is crucial in the rapidly evolving technological landscape. Additionally, the emphasis on teamwork and collaborative problem solving equips students with essensial STEM skills.

The research offers novel perspectives on the influence of educational robotics adoption to computational thinking abilities pertinent to integrated STEM learning circumstances. Synthesized from literature, the exploration focuses on the most effective way to integrate educational robotics into STEM learning and the benefit of educational robotics in the development of computational thinking.

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