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STEM-Robotics Training for Science Teachers: Designing Interactive Learning

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Abstract

This research explores the design and effectiveness of a training program for science teachers that aims to enhance interactive learning through STEM robotics. Using two main methods-training structures and hands-on activities-the research investigates how these approaches contribute to the development of critical skills among educators. The training structure focused on providing a comprehensive framework for integrating robotics into the science curriculum, while the hands-on activities emphasized practical application and experiential learning. The results showed that the STEM robotics-based learning design significantly improved teachers' ability to foster critical thinking, problem-solving, and computational thinking skills in their students. By equipping educators with these advanced instructional techniques, this research demonstrates how interactive learning environments can be effectively created to support and enhance STEM education.

Keywords: computational thinking skills, interactive learning, STEM Robotics

INTRODUCTION

STEM education, which stands for Science, Technology, Engineering, and Mathematics, is an integral part of modern teaching methodologies. It focuses on providing students with a holistic educational approach that combines various disciplines into one cohesive learning experience (Guzey et al., 2020). STEM education is important for several reasons. One of the

key reasons for the importance of STEM education is its role in preparing students for the future workforce (Tariq & Soomro, 2019). In today's rapidly evolving technological landscape, there is a growing demand for individuals with strong STEM skills. By exposing students to STEM education at an early age, they are better equipped to pursue careers in these fields and contribute to technological advancements (Muliyati et al., 2023). Additionally, STEM education helps develop critical thinking and problem-solving skills (Widya et al., 2019). It encourages students to think analytically, creatively, and logically to find innovative solutions to complex problems. Furthermore, integrating STEM into education helps bridge the gender gap in these fields (Admin, 2019). By providing equal opportunities for both male and female students to engage in hands-on STEM activities, educators can empower young girls to pursue careers in traditionally male-dominated fields like engineering and computer science (Venture, 2014).

One of the key components of STEM education is the integration of robotics into the curriculum (Darmawansah et al., 2023). Robotics provides an interactive and hands-on approach to learning that encompasses science, technology, engineering, and mathematics. It allows students to apply theoretical knowledge to real-world applications, fostering their creativity and problem-solving skills (Latip et al., 2020). Introducing robotics in STEM education ignites students' interest in the STEM fields by making learning more engaging and relevant. Through robotics, students can gain practical experience in coding, engineering design, and the application of mathematical concepts. This not only prepares them for future careers in technology and engineering but also cultivates a passion for innovation and discovery. Moreover, robotics in STEM education helps address the shortage of skilled professionals in these fields by nurturing a new generation of proficient and diverse STEM experts (Muliyati et al., 2023). By exposing students to robotics at an early age, educators can inspire them to pursue further studies and careers in STEM-related fields, subsequently contributing to technological advancements and addressing future workforce needs (Nugent et al., 2012).

The integration of robotics into STEM education has highlighted the need for training science teachers in STEM and robotics to enhance their teaching practices. Educators play a crucial role in delivering high-quality STEM education and fostering an interest in these fields among their students (Valko & Osadchyi, 2021). Therefore, providing professional development opportunities for teachers to develop their skills in STEM and robotics education is essential (Şahin et al., 2024). Furthermore, by empowering science teachers with the necessary training in STEM and robotics, schools can bridge the gap between theoretical knowledge and practical application, ultimately preparing students for future careers in technology, engineering, and other STEM-related fields. Additionally, such training will contribute to addressing the shortage of skilled professionals in these fields by nurturing a new generation of competent and diverse STEM experts.

Incorporating hands-on robotics activities into the curriculum can greatly enhance student engagement and learning outcomes (Fung et al., 2024). When students participate in building and programming robots, they are actively involved in the learning process (Essel et al., 2024). This hands-on approach not only makes the learning experience more enjoyable but also helps

students develop a deeper understanding of scientific and engineering concepts. By working on robotics projects, students can apply theoretical knowledge to solve real-world problems, fostering their critical thinking and problem-solving skills (Darmawansah et al., 2023). As they encounter challenges during the design and programming phases, they learn to analyze, troubleshoot, and implement solutions, which are essential skills in STEM fields. Moreover, hands-on robotics activities allow students to collaborate with their peers (Nemiro, 2020), promoting teamwork and communication. They can share ideas, troubleshoot together, and work towards a common goal, fostering a collaborative learning environment. Additionally, when students see the tangible results of their efforts in the form of a functioning robot, it boosts their confidence and motivation (Taylor & Baek, 2017). This sense of accomplishment encourages them to delve deeper into STEM subjects and pursue further studies and careers in related fields.

The training program for empowering science teachers to integrate robotics into their teaching aims to achieve several objectives:

- Developing Proficiency in Robotics Education: The primary objective of the training program is to equip science teachers with the necessary skills and knowledge to effectively integrate robotics into their teaching practices. This includes understanding the principles of robotics, programming, and engineering design, as well as learning how to incorporate hands-on robotics activities into the curriculum.
- Fostering Innovative Teaching Approaches: The program seeks to encourage science teachers to adopt innovative and interactive teaching methodologies by utilizing robotics as a tool for engaging students in STEM education. This objective focuses on empowering educators to create dynamic and stimulating learning environments that promote creativity, critical thinking, and problem-solving skills.
- Bridging Theory and Practice: By providing training in STEM and robotics education, the program aims to bridge the gap between theoretical knowledge and practical application for both teachers and students. Science teachers will learn how to effectively translate theoretical concepts into hands-on robotics projects, thereby enhancing the application of scientific and engineering principles in the classroom.
- Enhancing Student Engagement and Learning Outcomes: The program aims to empower science teachers to leverage robotics as a means to enhance student engagement and improve learning outcomes. By integrating hands-on robotics activities into the curriculum, teachers will be able to cultivate students' interest in STEM subjects and facilitate a deeper understanding of scientific and engineering concepts through practical application..

METHODS

TRAINING STRUCTURE

The STEM-Robotics training program is structured as an immersive learning experience, spanning over six weeks and delivered through a combination of in-person workshops, online

modules, and hands-on laboratory sessions. Tabel 1 shows structure of the training for science teachers.

TABLE 1. The Structure of STEM-Robotic Based Training for Science Teachers

No	Activity	Description Amount Hour (Lesson Hours)
1	Socialization of STEM-Based Training and Projection Robotics	2
2	Types of STEM Approach	2
3	Basic STEM Projects	2
4	Computational Thinking Skills	4
5	Coding for all levels	10
6	Robots as STEM tools	10
7	Robots to train Computaional Thinking Skills	10
	TOTAL	40

HANDS-ON ACTIVITIES AND WORKSHOPS

The planned computational thinking skills material is shown in Table 2.

TABLE 2. Planned Aspects of CT Skills Trained.

CT Skills Spectrum	Achievement Plan
Decomposition	• The process of breaking something, such as a complex problem, into smaller, more manageable parts. • Understanding place value or being able to describe storylines requires students to break the larger picture into smaller parts. Everyday tasks such as making schedules or shopping lists are also examples of decomposition; based on needs analysis and interviews with schools, these tasks have been held.
Pattern Recognition	• Analyze objects or ideas to expand or create patterns to understand the problem better. • The beginning of pattern recognition includes the ability to sort objects according to something like color, or learning to skip count..
Algorithms	• The development of steps used to solve a problem, often a series of sequential rules that are followed. • Solving math problems or writing computer programs are examples of algorithmic thinking. In Year 1 research, the spectrum of algorithmic CT emerged from the organization of steps with attention to logic and programming concepts.

During the STEM-Robotics training program, participants engage in practical, hands-on learning activities aimed at enhancing their understanding of robotics concepts and applications. These activities include building and programming robots, troubleshooting technical issues, and collaborating with peers to solve real-world challenges. Additionally, participants are provided with worksheets and clue cards that guide them through problem-solving exercises and stimulate critical thinking. These resources serve as valuable tools for reinforcing learning objectives and encouraging active participation in the training sessions. Through this combination of practical experience, worksheet exercises, and challenge-based

learning, participants develop a comprehensive understanding of robotics principles while honing their problem-solving skills in a dynamic and interactive learning environment.

FIGURE 1. Sphero Indi was chosen as a tool to develop a robotic-based STEM learning model for preschool and elementary school levels.

The concept of programming a robot with color blocks to be used is shown in Figure 2.

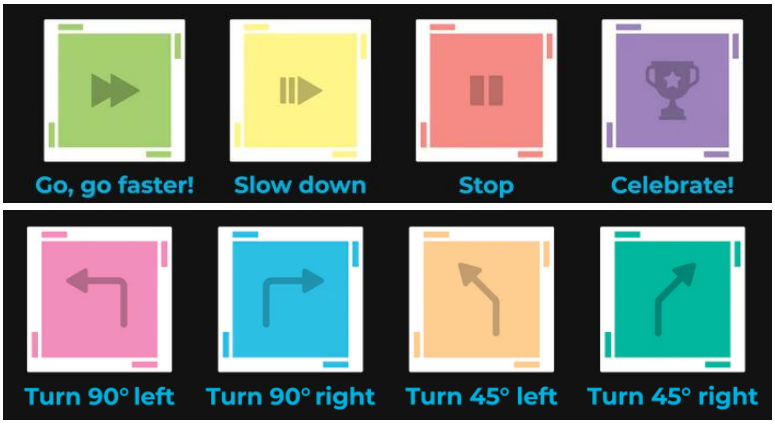

FIGURE 2. The color blocks that will be used in the programming stages of the Sphero Indi robot.

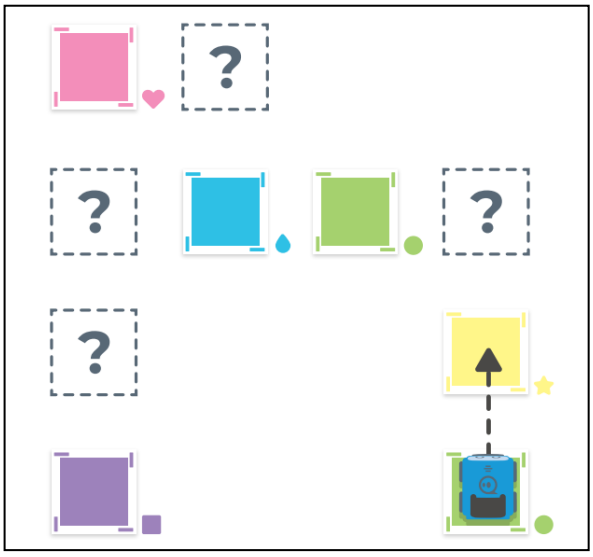

FIGURE 3. Card Challenge

RESULTS AND DISCUSSION

This article explores the transformative potential of incorporating robotics into STEM education. The article underscores how robotics training for science teachers can revolutionize their instructional approach by making learning more engaging and interactive. Robotics introduces a practical element to STEM subjects, allowing students to apply theoretical knowledge in practical scenarios. This hands-on approach not only enhances understanding, but also sparks students' curiosity and enthusiasm for science, technology, engineering and math (STEM). By integrating robotics, educators can move beyond traditional lecture-based methods and offer students dynamic learning experiences that connect classroom concepts with real-world applications.

Most of these articles focus on the design and implementation of STEM robotics training programs for teachers. This article highlights that such training should not only cover the technical aspects of robotics, but also equip teachers with effective pedagogical strategies. This includes developing lesson plans that incorporate robotics in ways that support educational standards and enhance student learning. This article suggests that a well-designed training program should be comprehensive, providing educators with both the technical skills to operate robotics and the instructional techniques to integrate it into their teaching practices. This dual focus ensures that teachers are not only capable of using robotics, but also adept at creating interactive and meaningful learning experiences for their students.

The training includes worksheets for teachers to complete. The worksheets also require teachers to create or invent their own challenges that can then be developed in learning activities.

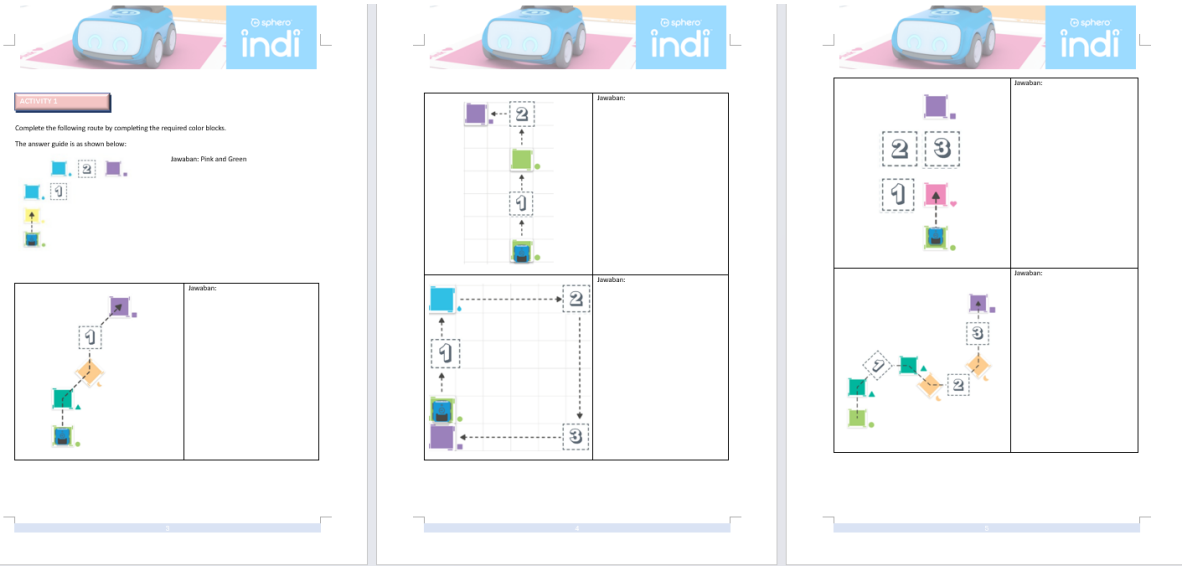

FIGURE 4. Challenges to be answered on the worksheet

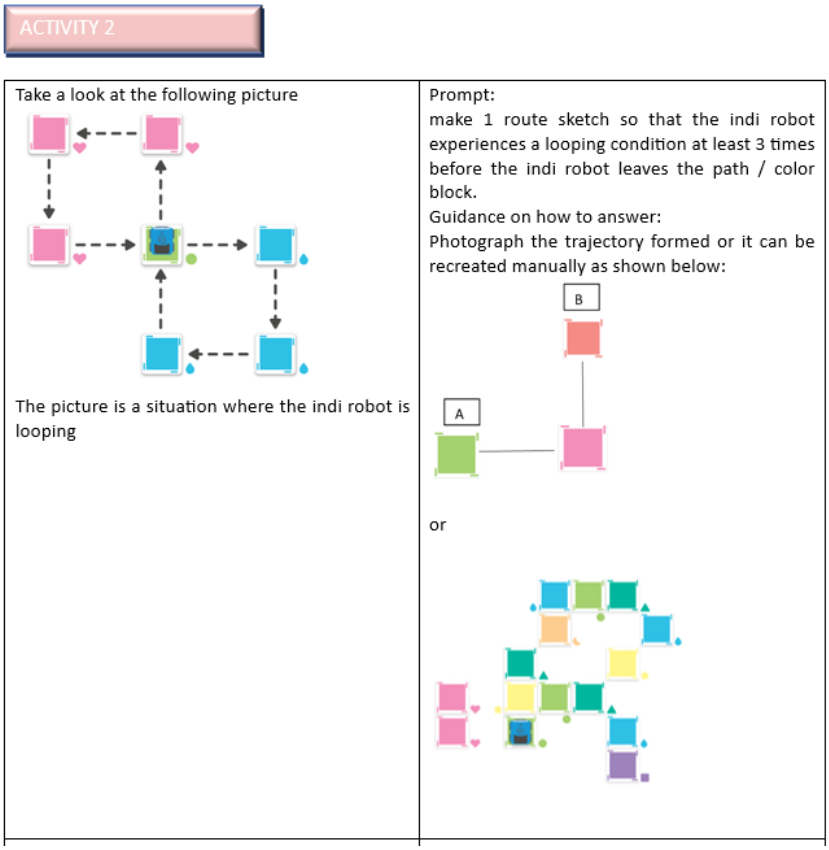

FIGURE 5. Activity where the teacher has to create the route himself

This article also discusses the impact of STEM-robotics training on teacher professional development. By participating in these training programs, teachers gain valuable skills and knowledge that can improve their teaching effectiveness and increase their confidence in using technology. These trainings often foster a collaborative learning environment where educators can share best practices and learn from each other. This professional growth is essential for adapting to the ever-evolving educational landscape and for integrating new technologies into the classroom. This article shows that continuous professional development is essential to keep teachers up-to-date with the latest advances in STEM education and to maintain high-quality instruction.

The challenges associated with implementing robotics in education are also discussed. The article notes that while robotics has significant potential, there are several barriers to its widespread adoption, including the cost of equipment, the need for ongoing technical support, and the requirement for adequate training. Schools may face difficulties in obtaining the necessary resources and funding to support robotics programs. In addition, teachers may need ongoing support and resources to effectively integrate robotics into their curriculum. To overcome these challenges, a coordinated effort from educational institutions, policymakers, and communities is needed to ensure that all schools have the necessary resources and support to effectively implement robotics.

CONCLUSION

This article emphasizes the substantial benefits of STEM-robotics training for science teachers, including increased student engagement and improved learning outcomes. However, it also highlights the need to address the challenges associated with the integration of robotics

in education. By providing robust training programs for teachers and addressing issues of resources and support, education stakeholders can maximize the potential of robotics to enrich STEM education. Successful implementation of robotics in the classroom can result in a more interactive, engaging and effective learning experience, ultimately preparing students for future careers in STEM fields.

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