

INVESTIGATING THE EFFECTIVENESS OF ROBOT-ASSISTED STEM EDUCATION: A MULTILEVEL META-ANALYSIS

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Abstract

This study investigates the effectiveness of robot-assisted STEM education through a multilevel meta-analysis method. Scientific articles published between 2010 and 2022 were analyzed. The findings confirm the positive impact of robotics on improving students' academic achievement, enhancing their attitude towards learning, and developing computational thinking skills. Furthermore, moderator factors such as teacher support, level of interactivity, subject area, education level, and duration of instruction were identified as influencing effectiveness. The results can inform both practical and theoretical recommendations for improving the organization of robot-assisted STEM education

Keywords: Educational robotics, STEM education, Computational thinking, Interactive learning, educational effectiveness, Robots in education, Meta-analysis, Learning motivation, educational technologies, Moderator factors.

Introduction

The rapid advancement of modern technology and science is creating new opportunities in the field of education. Educational robotics—an innovative tool that integrates mechanical engineering, electronic sensors, and artificial intelligence—plays a significant role in making the learning process more interactive and effective (Atman Uslu et al., 2022; Evripidou et al., 2020). In particular, in STEM fields (Science, Technology, Engineering, and Mathematics), robots are widely used as supportive tools to help students acquire knowledge and develop practical skills.

Previous studies have shown that robotics in STEM education positively affects students' knowledge acquisition, increases their motivation, and enhances computational thinking (Okita, 2014; Chin et al., 2014; Chalmers, 2018). However, some studies have also reported that robotics may not always be effective and can even negatively impact the learning process in certain contexts (Berland & Wilensky, 2015; Keren & Fridin, 2014). Therefore, it is essential to thoroughly examine the effectiveness of robot-assisted STEM education and identify the influencing factors.

Literature Review

Educational Robotics and STEM Education

Robotics plays a crucial role in automating human life (Wang et al., 2018). Educational robotics provides students with interactive and hands-on learning opportunities, enriching the learning

process and increasing student engagement (Atman Uslu et al., 2022; Mubin et al., 2013). Since STEM education integrates multiple disciplines, traditional teaching methods may not adequately support deep learning (Sapounidis & Alimisis, 2020). Robotics, however, proves effective in teaching complex scientific concepts through practical activities.

Impact of Robotics on STEM Education

Numerous studies have demonstrated that robotics significantly improves students' STEM knowledge and skills (Ferrarelli & Iocchi, 2021; Leonard et al., 2016). Moreover, robotics in education enhances students' attitudes toward learning by increasing their interest and enthusiasm (Anwar et al., 2019). Computational thinking (CT)—the ability to analyze and solve complex problems logically—also shows strong development through robotics (Ioannou & Makridou, 2018). However, in some cases, robots may distract students or interfere with the learning process (Berland & Wilensky, 2015).

STEAM education, based on the project-based learning method, emphasizes cognitive and creative exploration. This process involves acquiring knowledge through practical activity, applying it in practice, constructing various models during games, incorporating elements of technical creativity, and conducting inquiry-based learning.

STEAM education integrates interdisciplinary connections and project-based approaches, combining natural sciences with technology, engineering creativity, and mathematics. It also prepares students for careers in engineering and related fields.

Main Directions for Improving Teaching Methods and Approaches

Collaborative Teaching (Cooperative Learning):

In STEAM education, working in groups, thinking collectively, and solving problems together are of great importance.

When preparing teachers for collaborative teaching, they should be trained to exchange ideas in groups, analyze opinions, and make decisions together.

This method teaches students to work cooperatively, solve problems in groups, and find creative solutions.

Project-Based Learning:

In STEAM subjects, students acquire knowledge through practical, hands-on projects. This method develops students' creative and systematic thinking.

To successfully implement project-based learning, teachers need to encourage students to work both individually and in groups, and incorporate real-world problems into the projects.

This method not only helps students acquire knowledge, but also develops their independent working skills.

Use of Interactive Technologies:

Interactive teaching technologies help teachers ensure active participation of students. Online platforms, virtual laboratories, simulations, and other interactive tools engage students and make the learning process more interesting.

Teachers need to have the necessary knowledge and skills to effectively use interactive technologies.

Differentiated Approach:

In STEAM education, teachers should adapt their teaching methods based on the individual needs of students.

The differentiated approach allows teachers to provide instruction tailored to each student's developmental level.

This method enables students to learn at their own pace and maximize the development of their abilities.

Necessary Tools for Teacher Development

Mentoring and Peer Learning:

It is important to support teachers through mentoring, allowing them to share their knowledge and experience and adopt new methods.

By exchanging experiences with one another, teachers can improve their pedagogical practices

Moderator Factors

The effectiveness of robot-assisted STEM education is influenced not only by the technology itself but also by factors such as teacher support, type of interactivity, subject area, educational level, and duration of instruction (Byrne & Callaghan, 2014). Considering these moderators can lead to more effective implementation of robotics in the educational process.

Research Objectives and Questions

The main objective of this study is to evaluate the effectiveness of robot-assisted STEM education using multilevel meta-analysis. The study seeks to answer the following questions:

1. What is the overall effect size of robot-assisted STEM education?
2. How does robotics influence students' learning outcomes, attitudes toward learning, and computational thinking?
3. What moderator factors affect the effectiveness of robot-assisted STEM education, and how do they influence outcomes?

Methodology

Scientific articles were collected from databases such as Web of Science, Taylor & Francis, Scopus, IEEE, Wiley, and ACM, covering the period from 2010 to 2022. The selection criteria included studies that used robotics in STEM education, had an experimental or quasi-experimental design, and provided specific learning outcome data. Full texts of the articles were reviewed, and overall effect size was calculated.

Analysis and Results

The meta-analysis results confirmed that robot-assisted STEM education has a significant positive effect on improving students' knowledge, attitudes toward learning, and computational thinking. Robotics helped students better understand complex STEM concepts and apply them

to solve practical problems. Moreover, student motivation and interest increased. However, the level of effectiveness varied depending on teacher support, degree of interactivity, subject area, education level, and duration of the intervention. Hence, considering these factors is crucial when organizing robot-assisted educational processes.

Conclusion and Recommendations

Robot-assisted STEM education has been proven to be an effective tool in improving students' knowledge, skills, and motivation. At the same time, to maximize its effectiveness, it is necessary to consider various factors such as teacher support, educational format, and specific technological features. The findings of this study can contribute to advancing both educational practices and further academic research in this field.

References

1. T. Ismoilov & X. Majidova. **STEAM and SMART Education Technologies: A Methodological Guide**. Jizzakh, 2022, p. 54.
2. J.G. Yuldoshev, S.A. Usmonov. **Fundamentals of Pedagogical Technology**. Tashkent: O'qituvchi, 2004.
3. D.X. Alimova. **Methodological Significance of Using STEAM Educational Technology in Primary School Lessons**. <https://doi.org/10.5281/zenodo.10442440>, 2024.
4. Ishmuhamedov R.J. **Ways to Improve Educational Efficiency Through Innovative Technologies**, Tokent, 2009.
5. Golish L.V., Fayzullayeva D.M. **Planning and Designing Pedagogical Technologies**. Tashkent: TDPU, 2010.
6. F.M. Sabirova, T.I. Anisimova. **Theory and Practice of Implementing STEAM Education**. Kazan, 2022, p. 108. Published by decision of the Academic Council of Elabuga Institute, Kazan Federal University (Protocol No. 7, October 27, 2022)