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Systematic Review: Young Learners' Perception and Attitude toward Hands-On Activities for Learning STEM Education by Intervention of Educational Robotics

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ABSTRACT

STEM-focused education prepares elementary and secondary school students for 21st-century skills. Students can enhance their creativity and problem-solving skills by participating in Hands-on activities, using robots to teach STEM (Science, Technology, Engineering, and mathematics) in the classroom fosters interest and increases understanding of this multidisciplinary field. Previous studies have shown that Educational Robotics (ER) is an effective tool for understanding STEM concepts.

However, it is important to examine how robotics activities are encouraged in formal and informal school settings. This study aims to investigate "What are the students' perceptions and attitudes toward hands-on activities with the intervention of Educational Robotics (ER)?". We conducted a systematic review, by using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) methodology and analyzed the 11 experimental most relevant articles for elementary and secondary school students' perceptions, and learning experiences with hands-on activities by the intervention of robots. The study demonstrates students' attitudes toward learning change positively through hands-on activities. The findings suggest that further research is necessary to achieve more definitive results paper provides a discussion on China–Pakistan Economic Corridor (CPEC) and its potential contribution for the augmentation of regional connectivity between Pakistan and Central Asian Republics (CARs). CPEC is the main project of the Belt and Road Initiative (BRI) between China and Pakistan, comprising of industrial zones, pipest lines, energy, rail, and road segments for the trade of goods and energy from western Kashgar and running along the Lenart Highway through western Pakistan to Gwadar in the Arabian Sea. The corridor could link landlocked Central Asian countries to warmer water ports and better connections to South Asia, Middle East, as well as Africa. The study is qualitative and secondary source-based, policy report and official statements-based, and deals with strategic and economic and geopolitical relevance of CPEC. It believes that investment in transport infrastructure, customs harmonization, trade facilitation and development of energy cooperation can boost Pakistan – Central Asia connectivity. But political volatility, security concerns, poor infrastructure, among other regulatory constraints and regional rivalries are still major hurdles. The paper argues that CPEC has potential of helping to drive already going pan-Eurasian integration by means of continuous investment, institutional transformation and multilateral diplomacy.

Keywords: Educational robotics, hands-on activities, STEM, student perceptions, learning attitudes

INTRODUCTION

Research into the effects of Educational Robotics (ER) on students' social and intellectual skills has been steadily increasing. Educational robots are employed inside and outside classrooms to foster interest, engagement, and academic achievement in various STEM (Science, Technology, Engineering, and Mathematics) education disciplines (Anwar et al., 2019). The term "STEM" is pivotal in discussions, revolving around innovation, business, and competitiveness. It encompasses careers within these fields and is integral into education from preschool to university level (Marrero et al., 2014).

ER refers to a teaching method that uses robots to aid students in acquiring knowledge. This approach first emerged in the 1960s with the instructional method of Logo programming languages. This programmable device enhances the Project-

Based Learning (PBL) process (Misirli & Komis, 2016). Robotics education is a multidisciplinary field that can help young learners enter modern technology like mechanics, coding, electrical and mechanical engineering, mathematics, and physics. It offers a great opportunity for students to explore multiple fields at once (Dochshanov & Lapina, 2019). These platforms have various local and global capabilities, such as processing, sensing, and communicating. As a result, robots are capable of acting dynamically and autonomously (Jdeed et al., 2020).

Educational Robots are often used to create engaging transdisciplinary activities that integrate STEM education. Innovative machine-learning techniques are used to identify multiple paths for problem-solving and to teach the use of sensors during activities (Scaradozzi et al., 2020). Programming allows for the exploration of computational methods to aid in problem-solving. Active classroom learning is becoming increasingly important in education and facilitating the development of logical thinking skills. Computational thinking employs basic principles to solve complex problems. (Sáez López et al., 2021). Educational robots and programming activities enhance PBL and computational thinking skills. (Karaahmetoğlu & Korkmaz, 2019). STEM education focuses on PBL, which involves an integrated technology education program that enables students to apply their knowledge of science and math to solve real-world technology and engineering challenges (Julià & Antolí, 2019). Coding has become a vital skill in the 21st century. Scenario-Based Learning (SBL) can also help students improve their coding abilities for robotics (DEMİR KAÇAN & KAÇAN, 2022).

Various robotic kits are available for elementary and secondary classrooms including construction kits and programmable robots. For instance, KIBO robotics kit, Cubelets, LEGO Education WeDo, Sphero mini, Bee-Bot, Roamer, KUBO robot, Evo-Bit, and many others that suit both elementary and secondary school students (Papadakis, 2020). Robotics-based interventions can encourage young learners to learn with a positive attitude toward STEM careers. This approach is easy to implement, cost-effective, and can be integrated into a regular school day (Hudson et al., 2020). The Human-Centered Robotics (HCR) curriculum provides opportunities to participate in robotics. However, some obstacles might force them to prioritize one aspect over another. By developing and designing robots, students may experiment with trial and error (Gomoll et al., 2018).

Social and teleconferencing robots have been teaching tasks for a decade. In various forms, humanoid robots have proven to be potentially useful as teaching assistants. Social robots have particularly aided in the comprehensive mathematical concepts in middle school, and have shown positive results as effective teaching support (Konijn & Hoorn, 2020). The NAO (Ertuğrul et al., 2013) was the most popular choice in humanoid social robots. The Cozmo is another example of a social robot teaching and engaging school students in learning mathematical concepts such as algebra, geometry, and trigonometry in a fun and interactive way (Ahmad et al., 2020). The humanoid surveillance robot, Pepper, has limited abilities, but it has a certain charm that appeals to the human with it. It comes pre-installed with basic features such as speech synthesis, voice recognition, and facial detection. Pepper is an exciting addition for children, as it can engage and capture their attention, especially in kindergarten settings (Schiffer & Ferrein, 2018). PiBot was developed to enhance the quality of robotics education for secondary school students. It leverages the latest technologies to address the limitations of the current platform, such as the absence of cameras or the inability to support programming languages (Vega & Cañas, 2018).

Robot systems are great tools for STEM education due to their transdisciplinary nature. The robot is an easy concept to understand for students of all ages and skill levels. The Mona is an affordable, open-source, and open-hardware mobile robot that can be used in various programming environments (Arvin et al., 2019). Robotics is a constructive learning environment and a platform for STEM education, aimed at promoting science and technology among students from underrepresented communities, particularly girls. Realizing its potential depends primarily on designing course material and techniques and creating student assignments in the classroom (Barak & Assal, 2018).

LITERATURE REVIEW

According to (Kubilinskiene et al., 2017) robotics and the variety of tools created have resulted in more efficient use of robotics for various subjects and its applicability to a wider range of age groups. The scope of research into the use of robotics has been expanded. (Zhong & Xia, 2020) the study explores the potential effectiveness of using robots in mathematics education. Although robots have been used in mathematics education for a long time, there is a lack of quality empirical research on the effectiveness of robot-assisted mathematics education. (Jung & Won, 2018) This study explored the current trends of research on teaching robotics to young learners. It discussed methods and developments in this rapidly growing field of educational practice. (Anwar et al., 2019) The study discussed the effectiveness of ER in young learner's education in both formal and informal settings. It also provided a detailed review of ER and highlighted the benefits of using it in classrooms.

ER has a positive impact on students' engagement, motivation, and problem-solving abilities. (Amo et al., 2021) The study explores the teaching methodologies used in primary and secondary schools to teach sensors in robotics by using the Project-Based Learning (PBL) approach. (Darmawansah et al., 2023) The study focuses on the Robotics-based STEM (R-STEM) education industry, which uses technological-based learning models. The study explores various aspects of R-STEM education, including research trends, pedagogical approaches, diversity and inclusivity, assessment and evaluation methods, emerging technologies, challenges faced, and future directions. (Bano et al., 2023) The study highlights the potential effectiveness of ER for 21st-century skills development in young learners. ER is a valuable tool for comprehending STEM subjects. Robotics is an all-in-one tool that helps students learn 21st-century skills, gain knowledge, work as a team, and develop an interest in STEM

Teaching robotics enables students to gain hands-on experience and comprehend technical and mechanical systems. STEM is a popular educational topic in this modern world because it aids in various skills. This interdisciplinary approach has recently been formally and informally accepted in primary and secondary schools. ER is one of the newest trends in education in school from kindergarten to high school for learning. It promotes knowledge-building activities.

Robotics technology allows young learners to attain hands-on experience (Papadakis, 2020). The impact of ER in schools to understand STEM education is positive for learning future required skills. There is also a need to explore the perception and attitude of learners toward hands-on activities. We defined research questions for this purpose, which are mentioned in the third section of this study.

METHODOLOGY

Objective of the study

ER has emerged almost for two decades as a trend to help students better understand STEM concepts by providing an innovative instructional tool. This tool has a positive impact on learning and making it more effective. The literature has evidence of a few existing review studies regarding hands-on activities via educational robots in school, for example, (Benitti, 2012), (Kubilinskiene et al., 2017), (Jung & Won, 2018), (Anwar et al., 2019), (Amo et al., 2021), (Zhong & Xia, 2020) (Darmawansah et al., 2023), and (Bano et al., 2023). Our study differs from existing studies because it highlights the different aspects of this research area. These studies highlight the positive impact and benefits of this new learning trend in the educational environment at the school level.

It is crucial to delve into the perceptions and attitudes of young learners, particularly those aged between 9 to 13 years, who are typically in grades 6 to 8. This age group is at a pivotal stage in their educational journey, where their views on learning can significantly influence their engagement and enthusiasm for school activities. In this context, we aim to explore how this educational approach, specifically one that emphasizes hands-on learning, affects students' attitudes towards practical, interactive tasks by using robots. By conducting a thorough investigation into young learners' perceptions, we hope to gain valuable insights into their willingness to participate in such activities and how these experiences shape their overall attitudes toward learning. Understanding these factors is essential for effectively fostering an environment that promotes active participation and enhances educational outcomes.

To conduct this systematic review, we followed a standardized process based on the PRISMA (Preferred Reporting Items for Systematics Meta-Analysis) approach (Moher et al., 2009). The study aims to investigate elementary and secondary school students’ perceptions of ER in STEM education and their experience with hands-on activities. This section outlines the four steps in conducting a systematic review: Identification, Screening, Eligibility, and Inclusion. The structure of the review is based on this specific research question.

Research Question

What are the students' perceptions and attitudes toward hands-on activities with the intervention of Educational Robotics (ER)?

Keywords of Search in Online Databases

A systematic search was conducted following PRISMA guidelines to identify studies relevant to STEM education, educational robotics (ER), students' perceptions, and hands-on learning activities. A comprehensive Boolean search string was developed to capture the breadth of terminology used within this multidisciplinary field.

The following query was applied: ("STEM" OR "Educational Robotics" OR "students' perception") AND ("robots" OR "students" OR "perception" OR "attitude") AND ("robots" OR "students" OR "learning" OR "hands-on activities"), demonstrated in (Table 1). The first cluster (**"STEM," "Educational Robotics," "students' perception"**) targets the core domain of the review, ensuring coverage of studies focusing on technology-enhanced STEM learning. The second cluster (**"robots," "students," "perception," "attitude"**) captures research involving learner attitudes, engagement, and interactions with robotics. The third cluster (**"robots," "students," "learning," "hands-on activities"**) expands the search to include experiential learning contexts typically associated with ER and STEM interventions.

The query was applied to the **full-text collection**, allowing retrieval of articles even if the relevant terms appeared within the body of the text rather than only in titles, abstracts, or keywords. This approach increases sensitivity and minimizes the risk of omitting relevant studies. This structured search strategy ensured a comprehensive identification of literature aligned with the research questions and supported the transparency and reproducibility of the review process. Figure 1 illustrates the flow of information through the stages of identification, screening, eligibility, and inclusion. Based on the criteria for exclusions, a total of 11 studies were included in this literature review.

Table 1: The Search Strings in Databases

Databases	**Search String**
ACM Digital Library	("STEM" OR "Educational Robotics" OR "students' perception") AND ("robots" OR "students" OR "perception" OR "attitude") AND ("robots" OR "students" OR "learning" OR "hands-on activities")
IEEE Xplore	("STEM" OR "Educational Robotics" OR "students' perception") AND ("robots" OR "students" OR "perception" OR "attitude") AND ("robots" OR "students" OR "learning" OR "hands-on activities")
Google Scholar	("STEM" OR "Educational Robotics" OR "students' perception") AND ("robots" OR "students" OR "perception" OR "attitude") AND ("robots" OR "students" OR "learning" OR "hands-on activities")

Search Strategy and Selection

We began by searching for articles on our topic in the first step, and found a total of 665, with 149 from Google Scholar, 245 from IEEE, and 271 from the ACM Digital Library. In this second step, we found that 45 articles had no full-text availability. Additionally, we found that 559 were non-related. Then we reviewed the remaining 61 articles. Finally, we attained 34 articles that are related to STEM and ER. However, we found only 11 studies related to our research topic (Figure 1), showing the inclusion and exclusion flowchart based on the PRISMA methodology.

Exclusion and Inclusion Principles

We established clear exclusion criteria to refine the scope of our review. Studies focusing on pre-kindergarten learners, K–12 contexts, and high-school populations were excluded, as well as those targeting specific genders, countries, undergraduates, professionals, or any cohort outside pre-university education. We also eliminated reviews such as those summarizing, comparing, or extrapolating from other researchers' finding studies based solely on interviews, surveys, or individual reflections. Additionally, articles published before 2013 were excluded. Only experimental studies meeting our inclusion criteria were considered for the final analysis.

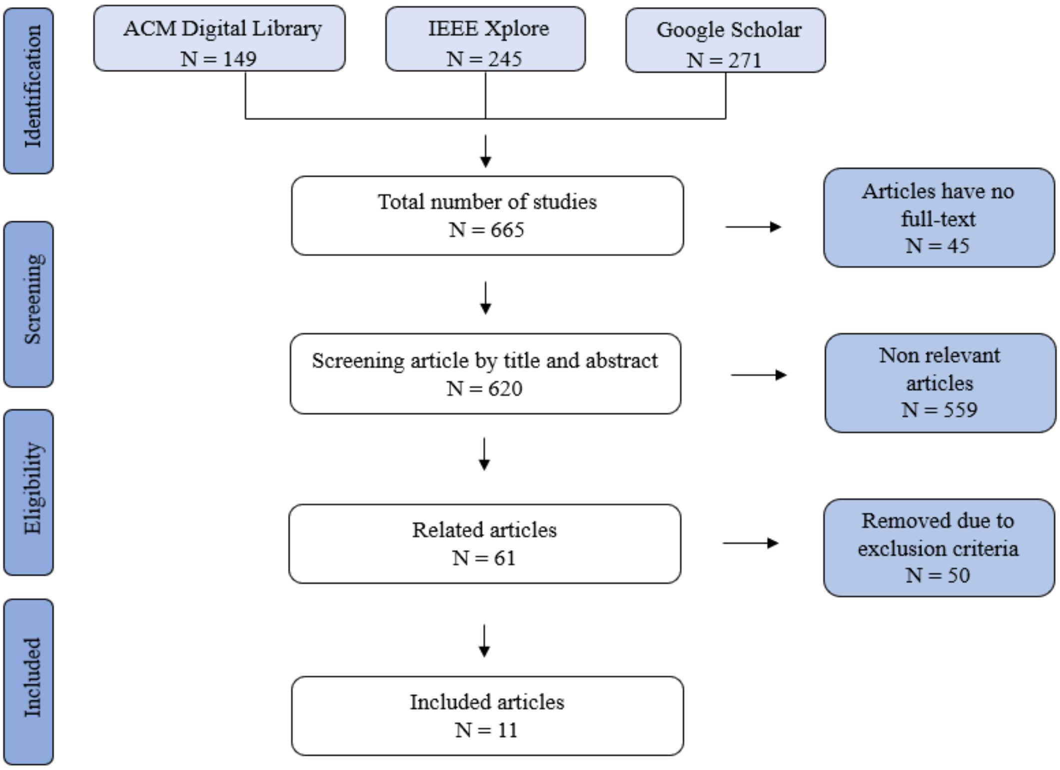

Figure 1: Flow chart of Selection Based on PRISMA Methodology

RESULTS

When searching for relevant publications, we found 61 articles related to elementary and secondary education. After a rigorous selection process, we ended up with 11 studies directly related to our topic. This revealed a lack of research on students' perceptions and attitudes toward hands-on activities. Secondary studies or analysis could not be a part of the findings in a systematic review. However, (Theodoropoulos, Antoniou, and Lepouras, 2017) study is an observational study of participants in a national competition in Greece, involving educators and students; teachers' responses are examined qualitatively. Whereas students' perceptions are described qualitatively, the results indicate a significant and positive impact on students' perceptions and attitudes towards these hands-on activities. The qualitative results are the reason for inclusion in this study. Furthermore, the research highlighted the question of whether ER should be introduced in the compulsory curriculum. Once we completed the study inclusion procedure, we presented the major findings in detail (Table 2). These findings have significant implications for this analysis, and their comprehensive nature will be valuable for academic and future research in this field.

The status of the research in this field has been analyzed and presented (Figure 2), and publications in the last ten years. This indicates a significant decline in research output and highlights the need for further investigation. It is alarming that no article was published in 2014, 2015, 2018, and 2022, while only one study was conducted in 2013, 2016, 2017, 2021, 2023, and 2024. In 2019 there were only two studies, and only in 2020 were three publications. Although numerous studies were published in 2025, but they did not meet our inclusive criteria

The situation is concerning and needs attention and future research to understand the impact of robotic hands-on activities on students' attitudes. Between 2013 and 2018 there was relatively little research and attention given to such hands-on activities by researchers and educators. However, in 2019, the topics caught the attention of researchers but unfortunately, due to the COVID-19 pandemic, progress was halted once again. As a result, little research was conducted in the following years. The pandemic situation has improved; it is time to consider working towards progress in this area.

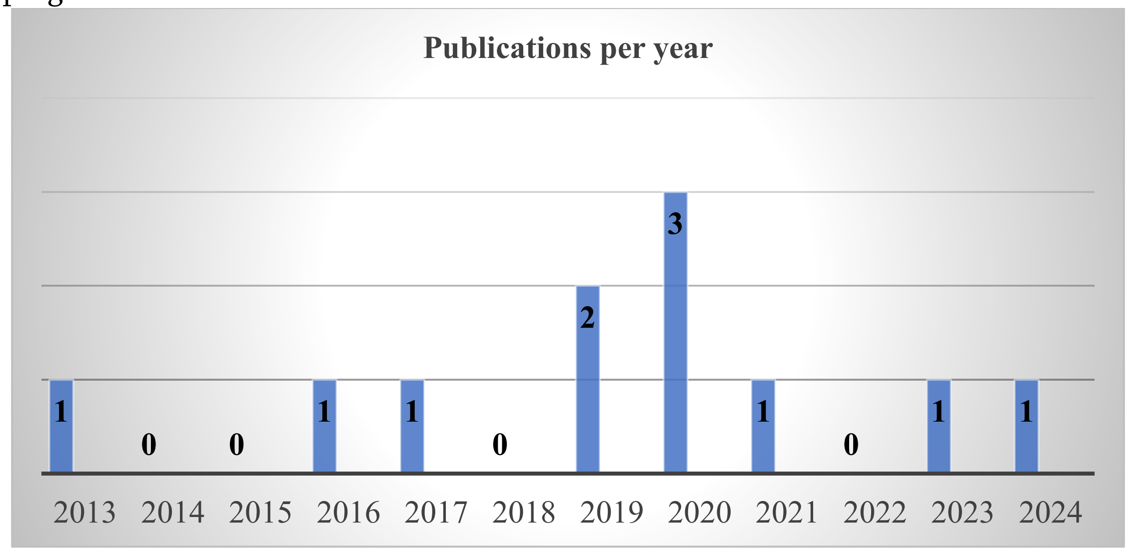

Figure 2: Publications per Year

Our comprehensive analysis delved into the efficiency of hands-on activities in elementary and secondary school learning environments, encompassing studies published from 2014 to 2024. We meticulously evaluated and categorized relevant studies based on their experimental framework and results. After analyzing the findings, we highlight the effectiveness of hands-on activities in elementary and secondary school education. Our study has primary objective is to define the Perceptions and attitudes of young learner's engaged in these activities using robots.

Table 2: The main key Findings of the Study

The main Findings	Source
The study emphasizes the significance of student well-being in STEM education as a crucial factor in assessing instructional methods.	(Campbell et al., 2024)
This study examines the changes in engineering interest and identification using multiple methods for high school and secondary students who attended an introductory engineering summer camp.	(Robinson, Kirn, and Amos, 2023)
This research investigates the impact of a STEM education program on students' attitudes toward technology over a while. This short-term activity has a positive effect on students' perception.	(Boeve-de Pauw et al., 2022)
The article demonstrates a model of innovative practice for organizing STEM education workshops for young learners. The results indicate that the proposed objective can be adapted in formal and informal settings.	(Storjak et al., 2020)
The study presents a practical example of a STEM project with elementary school students, using the software DunioBlochs4Kids to teach programming and promote interdisciplinary project-based learning.	(Scheffel et al., 2020)
The article aimed to investigate the impact of ER-based learning material on critical thinking skills, in science in elementary school students. The findings strongly support the integration of robotics concepts into the elementary education curriculum.	(Gorakhnath & Padmanabhan, 2020)
The study goal is to encourage students to pursue careers in STEM by engaging in relevant curricula. Additionally, the study aims to develop students' leadership skills in the STEM field and teach soft skills that will be useful in the future.	(Sheetz et al., 2019)
The study showed the effectiveness of the Scratch programming language. For this purpose, a course design consists of three modules on utilizing Scratch.	(Plaza et al., 2019)
The study is divided into two phases that examine the perception of teachers and students toward ER in a robotics competition and STEM helps to understand principles in computer science and engineering, particularly programming.	(Theodoropoulos, Antoniou, and Lepouras, 2017)
The study examines how cooperative robotics learning	(Mosley, Scollins,

impacted critical thinking by engaging in STEM for secondary school students. Results indicate that cooperative learning significantly enhances students' critical thinking skills.	and Van, 2016)
The paper presents the implementation of the "Whole School" program for the STEM initiative, which started with the sixth-grade class. Students who participated in STEM activities showed significantly higher levels of leadership, excitement, and achievement than other disciplines.	(Goodwin et al., 2013)

DISCUSSION

We analyzed the systematic review results to address the research question, what are the students' perceptions and attitudes toward hands-on activities with the intervention of Educational Robotics?

Hands-on activities positively engage young learners, and ER has several general benefits in elementary and secondary settings. ER intervention has the power to enhance 21st-century skills development in young learners, which is required in the future (Bano et al., 2023). STEM education can help students choose a career. However, despite these benefits, the research on students' perceptions is still missing, a significant gap that needs to be addressed. Several educational robots help enhance young learners' skills (Papadakis, 2020). Social robots also help to engage students. These social robots also help to understand mathematical concepts. (Ahmad et al., 2020). Competitions (Graffin et al., 2022) and summer camps (Mohr-Schroeder et al., 2014) Help to motivate and engage students in hands-on activities and engage underrepresented communities, especially females, these activities enhance their self-confidence and motivational level. Summer campus and challenges regarding conduct are also highlighted (Ucgul & Cagiltay, 2014).

STEM experience can spark interest and encourage secondary and high school students to explore interdisciplinary topics, including electrical engineering, computer programming, robotics, renewable energy, and civil engineering (Sheetz et al., 2019). The ER tools enable students to grasp the fundamental concepts of programming. Scratch is a tool that presents educational content in an ER and STEM framework. Elementary school students found these hands-on activities enjoyable (Plaza et al., 2019).

From the 11 findings, there is only one study (Goodwin et al., 2013) that is particularly conducted in a formal school setting. The topic of gender and underrepresented communities has been the subject of many studies, and most studies touch upon this topic. However, four studies (Goodwin et al., 2013), (Robinson et al., 2023), (Mosley et al., 2016), and (Theodoropoulos et al., 2017) delve into the subject of women in engineering, programming concepts, and writing skills. All four studies also discuss girls' participation in hands-on activities and their positive attitude toward these activities. Overall, this highlights the importance of encouraging and supporting girls' interest in STEM activities.

In the field of education, a study (Boeve-de Pauw et al., 2022) explores the impact of high-tech STEM activities on students' attitudes toward technology in the long and short term. The article delves into a unique aspect of the study where the 5th and 6th grade students' participants were evaluated for their interest in STEM intervention, after one day, three days, and twenty-one days. The result of the investigation showed consistent positive interest among participants in the STEM intervention one-day workshop. Additionally, the study highlights an interesting previous work, where the same participant was interviewed 12 years later, and it was found that they pursued engineering careers and had an engineering degree.

Numerous engineering institutes have established informal STEM education outreach programs for elementary, middle, and high school students. There is a need for further investigation to understand how these outreach programs impact students in middle school, particularly in terms of their choice of engineering as a major and career. Middle school is a crucial time for students to explore career choices. Accurate information about different opportunities is important at this age (Robinson et al., 2023). Ensuring young learners possess the necessary skills to engage actively in modern education. The opinion is shared by numerous researchers and educators who contend that primary and secondary education plays a vital role in addressing this issue (Boeve-de Pauw et al., 2022).

Perceptions and attitudes toward hands-on activities with the intervention of Educational Robotics

ER platforms have been thoroughly researched for their effectiveness in achieving desired learning outcomes at different educational levels. To bridge this gap, learners must be actively involved in the design process of these platforms. With the students' feedback and interest, we can create an engaging environment for STEM classes and enhance learning outcomes (Kyprianou et al., 2023). Another important aspect that needs to be discussed is the integrating culture and educational robotics in school settings to improve learning outcomes. Hands-on activities can help young learners develop their abilities, critical thinking, and problem-solving skills (Chou, 2018). Maker spaces in schools allow students to work on collaborative projects, experiment with tools and technology, and learn practical skills.

Furthermore, educational robots provide students with a platform to investigate creating a creative learning environment that encourages exploration and experimentation. Overall, incorporating maker culture and educational robots into schools promotes a comprehensive approach to teaching that prepares students to face future challenges (Marzoli et al., 2021). R as a learning tool is useful in education (Torres et al., 2025).On the other hand, the most significant challenge in the field of ER is the integration of robotics activities into school curricula. There is an increasing demand for robotics education in schools. It is often challenging to develop curricula that effectively incorporate robotics activities. Teachers must be trained in pedagogical approaches to robotics education, and students must have access to appropriate robotics equipment and resources. Additionally, there is a need for more research and development to address the issue of how to integrate robotics activities into school curricula, considering factors such as age-appropriateness, student engagement, and learning outcomes (Gorakhnath & Padmanabhan, 2020).

Competitions are a fantastic way to motivate and inspire students to learn about technology. However, ER is not yet part of the school curriculum. Participating in competitions introduces students to hands-on activities and changes their perception and attitude toward hands-on activities. Students can develop their skills in a fun and engaging way, while also building their confidence and enthusiasm for technology (Theodoropoulos, Antoniou, and Lepouras, 2017). There is a growing need for informal education outreach programs such as summer camps, especially for engineering interests and identifying development among middle-school-age students. However, there is a lack of research on the factors contributing to this development (Robinson et al., 2023). Hands-on activities have numerous difficulties and challenges. To conduct such kinds of activities we have a different environment to learn in a new way, and expert teachers are necessary for this, especially those with strong science backgrounds. For this reason, professional development is required.

Some important points require the attention of researchers and educationists, such as gender, diversity, and underrepresented communities. Many girls do not continue studying STEM subjects beyond the eighth grade. This has a profound impact on the STEM workforce and results in significant gender and ethnic disparity within the field. There is a need to encourage women and underrepresented communities to pursue STEM careers (Mosley, Scollins, and Van, 2016). STEM programs often target high school students, but it's important to acknowledge that many students especially girls, tend to lose interest in science and mathematics between the ages of 9 and 12. Therefore, we strongly believe that STEM initiatives must include elementary and secondary school students to increase the number of students who consider pursuing STEM careers (Goodwin et al., 2013). Participating in hands-on activities encourages diversity and inclusion in underrepresented communities and female engagement. These activities help create a sense of belonging and increase representation in various fields, which can lead to greater opportunities and a more inclusive society.

Actively engaging with diverse communities and supporting their participation, can foster more equality (Theodoropoulos et al., 2017). Various STEM outreach programs are available for middle and high school, especially female students and underserved minorities. It has been observed that many students develop an interest in engineering during their middle school or early high school years. Informal out-of-school experience in science and engineering provides excellent opportunities for students to engage in and develop an interest in pursuing science and engineering in college and a potential career in the future (Robinson et al., 2023).

Short-term and long-term STEM interventions have consistently improved students' attitudes toward STEM learning. Short programs lasting from eight weeks to two months (Khine, 2017) have reliably increased enthusiasm, confidence, and interest in STEM. This suggests that hands-on, inquiry-based tasks provide immediate motivational benefits for young learners. However, these improvements appear fragile, and the authors emphasize the need for ongoing reinforcement to maintain positive attitudes beyond the intervention period.

In contrast, longer, more sustained programs have demonstrated deeper and more lasting changes in attitudes. Multi-year interventions (Leonard et al., 2016) gradually enhance STEM identity, self-efficacy, and perceptions of relevance. This indicates that consistent exposure and high-quality instruction are essential for long-term impact. Similarly, the one-year program reported by (Gorakhnath & Padmanabhan, 2020) showed significant growth in students' confidence and perceived usefulness of STEM, highlighting the advantages of continuity compared to shorter implementations. Studies that incorporate robotics and inquiry-based learning further indicate that technology-rich, collaborative environments enhance curiosity, engagement, and conceptual understanding. However, sustaining these benefits requires continued access to resources and teacher support. Overall, the evidence suggests that while short-term STEM activities can ignite interest, lasting improvements in attitudes depend on structured, ongoing experiences that are integrated throughout the curriculum.

CONCLUSION

This study systematically presents students' perceptions and attitudes toward hands-on activities at the elementary and secondary levels. The study also identifies the involvement of girls and underrepresented communities in these activities and the benefits of participation in summer camps and competitions. Additionally, it explores the role of hands-on activities in promoting diversity and the associated difficulties and challenges.

According to this study searched for articles from 3 databases. Only 61 articles discussed students' perceptions and attitudes toward hands-on activities, and only 11 studies yielded productive outcomes regarding elementary and secondary school-level students' perceptions and attitudes. The research is limited at this level. Further investigation is required. This study also presents findings, and responses to the research question, based on existing literature. The results indicate a significantly positive impact of hands-on activities on students. Furthermore, the study highlights that such activities help to enhance students' interest in technology. Considering these results, future work should focus on more experimental studies and investigations.

For this study, we used a transparent selection process, but there are limitations to this approach. While we included those studies that met our criteria, we did not screen based on methodology or reporting quality. Our study scope is limited to one decade, which may not provide a comprehensive overview of all aspects.

The research also identifies the importance of hands-on robotics activities related to technological advancements in education. It enables students to apply theoretical knowledge to real-world scenarios. The findings provide valuable insights for educators, practitioners, and researchers in the field of technology education and help them better understand its benefits and how they can be incorporated into the curriculum for the benefit of learners.

The systematic review shows that hands-on STEM activities by intervention educational robotics (ER) provide significant benefits for elementary and secondary learners. Such activities enhance engagement, motivation, and 21st-century skills while increasing students' confidence and interest. However, gaps exist in understanding students' perceptions of hands-on and robotics-based learning, especially within formal school settings. Gender disparities also remain, and while these activities can support girls and underrepresented groups, ongoing efforts are needed for equitable participation and retention. Informal learning environments, such as camps and competitions, are beneficial, but their long-term effects require further study.

Recommendations

Based on the overall findings, several key recommendations have emerged to strengthen the effectiveness of hands-on STEM education and educational robotics (ER) initiatives. First, schools should integrate robotics, programming, and maker-based learning directly into the curriculum, providing sustained, long-term STEM experiences instead of relying solely on short-term workshops. To support this shift, it is essential for teachers to receive consistent professional development, especially in inquiry-based pedagogies and robotics integration.

Additionally, promoting inclusive participation is crucial. Schools should actively encourage girls and students from underrepresented communities to engage in STEM activities. Policymakers can further support these efforts by allocating funding for ER equipment, expanding outreach programs such as camps and competitions, and developing curriculum frameworks that include age-appropriate robotics activities. Researchers need to address existing gaps by conducting more studies in formal school settings, exploring the long-term effects of STEM participation, and examining gender and diversity-related factors that influence engagement. Finally, designers of educational robotics tools should prioritize student-centered and developmentally appropriate platforms that foster collaboration, critical thinking, and inquiry-based learning.

REFERENCES

Ahmad, M. I., Khordi-Moodi, M., & Lohan, K. S. (2020). Social robot for STEM education. *ACM/IEEE International Conference on Human-Robot Interaction*, 90–92. https://doi.org/10.1145/3371382.3378291

Amo, D., Fox, P., Fonseca, D., & Poyatos, C. (2021). Systematic review on which analytics and learning methodologies are applied in primary and secondary education in the learning of robotics sensors. *Sensors (Switzerland)*, *21*(1), 1–21. https://doi.org/10.3390/s21010153

Anwar, S., Bascou, N. A., Menekse, M., & Kardgar, A. (2019). A systematic review of studies on educational robotics. *Journal of Pre-College Engineering Education Research*, *9*(2), 19–42. https://doi.org/10.7771/2157-9288.1223

Arvin, F., Espinosa, J., Bird, B., West, A., Watson, S., & Lennox, B. (2019). Mona: an Affordable Open-Source Mobile Robot for Education and Research. *Journal of Intelligent and Robotic Systems: Theory and Applications*, *94*(3–4), 761–775. https://doi.org/10.1007/s10846-018-0866-9

Bano, S., Atif, K., & Mehdi, S. A. (2023). Systematic review: Potential effectiveness of educational robotics for 21st century skills development in young learners. *Education and Information Technologies*, 1–19. https://doi.org/10.1007/S10639-023-12233-2/TABLES/2

Barak, M., & Assal, M. (2018). Robotics and STEM learning: students' achievements in assignments according to the P3 Task Taxonomy—practice, problem solving, and projects. *International Journal of Technology and Design Education*, *28*(1), 121–144. https://doi.org/10.1007/s10798-016-9385-9

Benitti, F. B. V. (2012). Exploring the educational potential of robotics in schools: A systematic review. *Computers and Education*, *58*(3), 978–988. https://doi.org/10.1016/j.compedu.2011.10.006

Boeve-de Pauw, J., Ardies, J., Hens, K., Wullemen, A., Van de Vyver, Y., Rydant, T., De Spiegeleer, L., & Verbraeken, H. (2022). Short and long term impact of a high-tech STEM intervention on pupils' attitudes towards technology. *International Journal of Technology and Design Education*, *32*(2), 825–843. https://doi.org/10.1007/s10798-020-09627-5

Campbell, T., Neequaye, B., Hillier, C., & Singh, D. (2024). Exploring how learning by 'talking and doing' supports flourishing in S.T.E.M for elementary students. *Cogent Education*, *11*(1). https://doi.org/10.1080/2331186X.2024.2315819

Chou, P. N. (2018). Skill Development and Knowledge Acquisition Cultivated by Maker Education: Evidence from Arduino-based Educational Robotics. *Eurasia Journal of Mathematics, Science and Technology Education*, *14*(10), 1–15. https://doi.org/10.29333/ejmste/93483

Darmawansah, D., Hwang, G. J., Chen, M. R. A., & Liang, J. C. (2023). Trends and research foci of robotics-based STEM education: a systematic review from diverse angles based on the technology-based learning model. *International Journal of STEM Education*, *10*(1). https://doi.org/10.1186/s40594-023-00400-3

DEMİR KAÇAN, S., & KAÇAN, A. (2022). Looking for Problem Scenarios with Robotic Coding: Primary School Example in Turkey. *International Journal of Psychology and Educational Studies*, *9*(2), 525–538. https://doi.org/10.52380/ijpes.2022.9.2.603

Dochshanov, A. M., & Lapina, M. (2019). Robotics in STEM education: A multiperspective strategy case study. *CEUR Workshop Proceedings*, *2494*(May), 20–23.

Ertuğrul, B. S., Gurpinar, C., Kivrak, H., & Kose, H. (2013). *Insansı Robot destekli Interaktif İşaret Dili Eğitimi için İşaret Tanıma Gesture Recognition for Humanoid Assisted Interactive Sign Language Tutoring*.

Gomoll, A., Šabanović, S., Tolar, E., Hmelo-Silver, C. E., Francisco, M., & Lawlor, O.

(2018). Between the Social and the Technical: Negotiation of Human-Centered Robotics Design in a Middle School Classroom. *International Journal of Social Robotics*, *10*(3), 309–324. https://doi.org/10.1007/s12369-017-0454-3

Goodwin, M., Brawley, M., Ferguson, P., Price, D., & Whitehair, J. (2013). A Whole-School approach to STEM education: Every child, every class, every day. *ISEC 2013 - 3rd IEEE Integrated STEM Education Conference*, 1–4. https://doi.org/10.1109/ISECon.2013.6525203

Gorakhnath, I., & Padmanabhan, J. (2020). Educational robotics through LEGO for enhancing critical thinking skill in science. *Journal of Critical Reviews*, *7*(19), 1303–1312. https://doi.org/10.31838/jcr.07.19.159

Graffin, M., Sheffield, R., & Koul, R. (2022). 'More than Robots': Reviewing the Impact of the FIRST® LEGO® League Challenge Robotics Competition on School Students' STEM Attitudes, Learning, and Twenty-First Century Skill Development. *Journal for STEM Education Research*, 322–343. https://doi.org/10.1007/s41979-022-00078-2

Hudson, M.-A., Baek, Y., Ching, Y., & Rice, K. (2020). Using a Multifaceted Robotics-Based Intervention to Increase Student Interest in STEM Subjects and Careers. *Journal for STEM Education Research*, *3*(3), 295–316. https://doi.org/10.1007/s41979-020-00032-0

Jdeed, M., Schranz, M., & Elmenreich, W. (2020). A study using the low-cost swarm robotics platform spiderino in education. *Computers and Education Open*, *1*(October), 100017. https://doi.org/10.1016/j.caeo.2020.100017

Julià, C., & Antolí, J. Ò. (2019). Impact of implementing a long-term STEM-based active learning course on students' motivation. *International Journal of Technology and Design Education*, *29*(2), 303–327. https://doi.org/10.1007/s10798-018-9441-8

Jung, S. E., & Won, E. S. (2018). Systematic review of research trends in robotics education for young children. *Sustainability (Switzerland)*, *10*(4), 1–24. https://doi.org/10.3390/su10040905

Karaahmetoğlu, K., & Korkmaz, Ö. (2019). The effect of project-based arduino educational robot applications on students' computational thinking skills and their perception of basic stem skill levels. *Participatory Educational Research*, *6*(2), 1–14. https://doi.org/10.17275/per.19.8.6.2

Khine, M. S. (2017). Robotics in STEM Education. In *Robotics in STEM Education*. https://doi.org/10.1007/978-3-319-57786-9

Konijn, E. A., & Hoorn, J. F. (2020). Robot tutor and pupils' educational ability: Teaching the times tables. *Computers and Education*, *157*(December 2019), 103970. https://doi.org/10.1016/j.compedu.2020.103970

Kubilinskiene, S., Zilinskiene, I., Dagiene, V., & Sinkevičius, V. (2017). Applying Robotics in School Education: a Systematic Review. *Baltic Journal of Modern Computing*, *5*(1), 50–69. https://doi.org/10.22364/bjmc.2017.5.1.04

Kyprianou, G., Karousou, A., Makris, N., Sarafis, I., Amanatiadis, A., & Chatzichristofis, S. A. (2023). Engaging Learners in Educational Robotics:

Uncovering Students' Expectations for an Ideal Robotic Platform. *Electronics*, *12*(13), 2865. https://doi.org/10.3390/electronics12132865

Leonard, J., Buss, A., Gamboa, R., Mitchell, M., Fashola, O. S., Hubert, T., & Almughyirah, S. (2016). Using Robotics and Game Design to Enhance Children's Self-Efficacy, STEM Attitudes, and Computational Thinking Skills. *Journal of Science Education and Technology*, *25*(6), 860–876. https://doi.org/10.1007/s10956-016-9628-2

Marrero, M. E., Gunning, A. M., & Germain-williams, T. (2014). What is STEM Education ? Why is STEM Education Perspectives on the " STEM. *Global Education Review*, *1*, 1–6.

Marzoli, I., Rizza, N., Saltarelli, A., & Sampaolesi, E. (2021). Arduino: From Physics to Robotics. In *Lecture Notes in Networks and Systems* (Vol. 240). https://doi.org/10.1007/978-3-030-77040-2_41

Misirli, A., & Komis, V. (2016). *Robotics and Programming Concepts in Early Childhood Education : A Conceptual Framework for Designing Educational Scenarios Robotics and Programming Concepts in Early Childhood Education : A Conceptual Framework for Designing Educational*. *January*. https://doi.org/10.1007/978-1-4614-6501-0

Moher, D., Liberati, A., Tetzlaff, J., & Altman, D. G. (2009). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Journal of Clinical Epidemiology*, *62*(10), 1006–1012. https://doi.org/10.1016/j.jclinepi.2009.06.005

Mohr-Schroeder, M. J., Jackson, C., Miller, M., Walcott, B., Little, D. L., Speler, L., Schooler, W., & Schroeder, D. C. (2014). Developing Middle School Students' Interests in STEM via Summer Learning Experiences: See Blue STEM Camp. *School Science and Mathematics*, *114*(6), 291–301. https://doi.org/10.1111/ssm.12079

Mosley, P., Scollins, L., & Van, P. (2016). Robotic Cooperative Learning Promotes Student STEM Interest. *American Journal of Engineering Education-December*, *7*(2), 117–128.

Papadakis, S. (2020). Robots and Robotics Kits for Early Childhood and First School Age. *International Journal of Interactive Mobile Technologies*, *14*(18), 34–56. https://doi.org/10.3991/ijim.v14i18.16631

Plaza, P., Sancristobal, E., Carro, G., Blazquez-Merino, M., Garcia-Loro, F., Munoz, M., Albert, M. J., Morinigo, B., & Castro, M. (2019). Scratch as Driver to Foster Interests for STEM and Educational Robotics. *Revista Iberoamericana de Tecnologias Del Aprendizaje*, *14*(4), 117–126. https://doi.org/10.1109/RITA.2019.2950130

Robinson, T., Kirn, A., & Amos, J. (2023). The Effects of Engineering Summer Camps on Middle and High School Students' Engineering Interest and Identity Formation: A Multi-methods Study. *Journal of Pre-College Engineering Education Research*, *13*(2), 84–106. https://doi.org/10.7771/2157-9288.1351

Sáez López, J. M., Otero, R. B., & De Lara García-Cervigón, S. (2021). Introducing

robotics and block programming in elementary education. *RIED-Revista Iberoamericana de Educacion a Distancia*, *24*(1), 95–113. https://doi.org/10.5944/ried.24.1.27649
Scaradozzi, D., Cesaretti, L., Screpanti, L., & Mangina, E. (2020). Identification of the Students Learning Process During Education Robotics Activities. *Frontiers in Robotics and AI*, *7*(March), 1–12. https://doi.org/10.3389/frobt.2020.00021
Scheffel, E., Queiroz, R. L., Sampaio, F. F., & Motta, C. L. R. da. (2020). Hands-on STEAM: learning to program in Elementary School using Directed Elaboration. *Hands on Science HSci …*, *July*. https://www.researchgate.net/profile/Erica-Scheffel/publication/349547555_Hands-on_STEAM_learning_to_program_in_Elementary_School_using_Directed_Elaboration/links/6035c8cb299bf1cc26e7ecaf/Hands-on-STEAM-learning-to-program-in-Elementary-School-using-Direc
Schiffer, S., & Ferrein, A. (2018). Erika—early robotics introduction at kindergarten age. *Multimodal Technologies and Interaction*, *2*(4). https://doi.org/10.3390/mti2040064
Sheetz, L., Ivy, S., Conn, D. B., & Motupalli, J. (2019). Developing a Model for Increasing Leadership and Diversity in STEM through Mobile STEM Workshops, Collaboration, and Community Involvement. *2019 IEEE Integrated STEM Education Conference (ISEC)*, 129–135. https://doi.org/10.1109/isecon.2019.8882009
Silva, R. (2024). *Pre-service teachers ' perceptions towards integrating educational robotics in the primary school*. *20*(4).
Storjak, I., Pushkar, L., Jagust, T., & Krzic, A. S. (2020). First steps into STEM for young pupils through informal workshops. *Proceedings - Frontiers in Education Conference, FIE*, *2020-Octob*, 2–6. https://doi.org/10.1109/FIE44824.2020.9274139
Theodoropoulos, A., Antoniou, A., & Lepouras, G. (2017). Teacher and student views on educational robotics: The Pan-Hellenic competition case. *Application and Theory of Computer Technology*, *2*(4), 1. https://doi.org/10.22496/atct.v2i4.94
Torres, G., Juliete, C., Maia, A., Fernandes, C., Terra, L., Marcos, L., & Gonçalves, G. (2025). *Educational robotics as a pedagogical resource for K-12 students with learning difficulties*. 1–18.
Ucgul, M., & Cagiltay, K. (2014). Design and development issues for educational robotics training camps. *International Journal of Technology and Design Education*, *24*(2), 203–222. https://doi.org/10.1007/s10798-013-9253-9
Vega, J., & Cañas, J. M. (2018). PiBot: An open low-cost robotic platform with camera for STEM education. *Electronics (Switzerland)*, *7*(12). https://doi.org/10.3390/electronics7120430
Zhong, B., & Xia, L. (2020). A Systematic Review on Exploring the Potential of Educational Robotics in Mathematics Education. *International Journal of Science and Mathematics Education*, *18*(1), 79–101.

https://doi.org/10.1007/s10763-018-09939-y