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EDUCATIONAL ROBOTICS AND SCIENCE EDUCATION: AN EMPIRICAL REVIEW

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Introduction

In recent years, robots have been recognized as valuable tools to enhance student motivation and academic performance, leading to significant advancements in educational technology. Educational robotics, defined as the study aimed at improving learning experiences through robot-related activities, spans all educational levels and encompasses various subjects. It fosters an engaging learning environment for real-world problem-solving. Robotics in the classroom supports 21st-century teaching methods, particularly in STEM fields, while promoting creativity, cognitive skills, and active learning. Additionally, robotics helps develop critical thinking, problem-solving, collaboration, and teamwork skills, making it adaptable for students of all abilities, including those with special needs.

Robotics education equips students with essential skills for a technology-driven future, enhancing their abilities in science, engineering, technology, and mathematics, as well as fostering social, design, communication, and creativity skills. It also offers significant benefits for special needs education by helping children overcome learning barriers. Additionally, educational robots provide various advantages, as noted by Matthew et al. (2022).

i. Preparing students for future career opportunities
ii. Helping remote students access their school
iii. Help the students to develop teamwork and co-operative skills
iv. Increases Creative and innovative skills of students
v. Help the students to communicate and learn different advanced technological platforms
vi. Simplify complex programming from a young age
vii. Support students with special needs
viii. Promote the development of cognitive skills among children and young people
ix. Stimulate imagination and creativity
x. Help students deepen their knowledge of robotics and programming
xi. Make STEM simple and fun to learn

Educational robots can they help young students develop cognitive skills and mathematical thinking at an early age. They also give them skills that they can transfer to other areas of their learning.

Robotics in Science Education

Robotics in science education creates a more engaging learning environment, particularly for problem-solving and critical thinking tasks. This innovative approach encourages the integration of robotics to promote engineering concepts and interdisciplinary practices (Bargagna et al., 2019; Ferreira et al., 2018). Anwar et al. (2019) highlighted the importance of combining robots with STEM learning to inspire students who may not initially show interest in these fields. Artificial intelligence (AI) further enhances this integration by facilitating instructional activities that actively involve students (Hwang et al., 2020). Engaging with robotics helps develop essential skills like critical thinking, creativity, collaboration, and problem-solving, as students tackle real-world challenges using science process skills (Evripidou et al., 2020).

More so, robots has been submitted to have the potential to offer children an innovative and enjoyable educational setting in which they can actively participate in the study of Science by providing a rich learning environment that combines STEM principles with hands-on experience and creative thinking. According to Fajrina et al. (2020) integrated STEM learning is one of the appropriate approaches to be applied in the learning process as an effort to cultivate 4C skills (critical thinking, creativity, collaboration and communication). Jawad et al., (2021) in their research obtained results that with STEM learning they could develop innovative thinking, improve the performance of their students, because with STEM learning an atmosphere of passion can be created that attracts students to the field, motivates learning, creativity and innovation.

According to Zhumaniyaz (2023), educational robots can improve student learning by encouraging creativity and innovation and offering practical experiences in STEM (science, technology, engineering, and math) education. According to similar findings, educational robots have a good impact on students' creativity in STEM education and can raise learning motivation, according to research by Shih-kai and Hung-Chung (2023). Numerous research have looked into how instructional robots affect students' academic achievement. The usage of educational robots has been found to positively correlate with academic achievement, especially in STEM (science, technology, engineering, and mathematics) fields (Brown & Howard, 2021). Working with robots is hands-on and gives practical application in addition to reinforcing theoretical principles, which enhances comprehension of the subject matter.

Challenges of Educational Robots

Educational robots face several challenges in the realm of education:

1. Fear of Displacement: Students may feel that robots are replacing their teachers.
2. Emotional Attachment: Humanoid robots can create misleading emotional connections for children, affecting their learning if the robot is lost or damaged.
3. Training: Teachers need proper training to use educational robots effectively; inadequate training can hinder learning.
4. Technology Reliability: Robots can fail, raising concerns about their reliability in educational settings.
5. Cost: High maintenance costs limit the widespread use of educational robots.
6. Appearance of the Robot: A human-like appearance might instill fear in learners, hindering the learning process.
7. Safety: Some robots may have sharp edges, posing safety risks to children and deterring them from using the technology.

Improvisation (Robotic) in Science Education

Robotic improvisation entails the innovative and flexible application of robotic tools and technology to enhance science education, especially in settings with limited resources. Teachers, through leveraging low-cost alternatives and innovation, can design instructional activities that combine theoretical knowledge with practical experiences, helping students develop a deeper understanding of scientific processes and principles (Bargagna et al., 2019).

Strategies for Robotic Improvisation in Science Teaching

The following strategies can be applied in improvising robots for effective science teaching:

i. By creating simple robotic models out of inexpensive materials like recycled motors, electronic components, and mechanical parts, Teachers can expose students to robotics concepts (Fabiyi et al., 2016).
ii. Robotics can be incorporated into the science curriculum to teach concepts such as electricity, mechanics, and programming. For example, using a robotic arm to demonstrate simple machines or Newton’s laws of motion (Çakır et al., 2021).
iii. Teachers can adopt project-based learning strategies, where students are tasked with designing and building robots to solve specific problems. This promotes inquiry-based learning and reinforces theoretical knowledge (Iroju et al., 2019).

iv. In resource-limited schools, virtual robotics platforms such as Robo Blockly, Tinkercad, or CoderZ can be used to simulate and teach robotics concepts without requiring physical kits (Alsoliman, 2022).

Implementing robotic improvisation in science teaching presents several challenges as captured by Essien and Ntui, 2024 including high costs of robotics kits, lack of teacher technical skills, component breakdowns requiring maintenance, and barriers for schools without electricity or internet access. Despite these challenges, robotic improvisation offers significant benefits, enhancing science education for secondary students by promoting hands-on learning, collaboration, and skills such as critical thinking, creativity, and problem-solving.

Empirical Review

Various researches have been carried out on the effects of educational robotics on students.

Essien and Ntui (2024) examine the integration of robotics into Nigeria's educational system, highlighting its transformative potential in enhancing competencies in STEM fields. Despite challenges like inadequate funding, poor infrastructure, and a lack of qualified teachers, robotics education can significantly boost student engagement, critical thinking, and problem-solving skills. The paper discusses the evolution of robotics, current trends in education, and the barriers to widespread implementation. It also offers strategic recommendations for overcoming these obstacles, emphasizing the need for collaboration among stakeholders to ensure equitable access and sustainable robotics education, ultimately contributing to Nigeria's national development and alignment with global educational trends.

Fabiyi et al. (2016) reviewed the introduction of robotics into the Nigerian secondary school curriculum, emphasizing its potential to empower youth to address technological challenges. The study questioned why robotics hasn't been fully adopted, suggesting that government officials may doubt its economic impact. It analyzed potential benefits such as job creation, increased interest in engineering and computer science, improved academic performance, and bridging the digital divide while also discussing challenges and proposing solutions.

Afonso et al. (2021) studied the impact of educational robotics on learning and motivation among 66 4th grade students in the Programming and Robotics Club (PRC) at Agrupamento de Escolas de Monserrate (AEM). The activities covered various subjects, including electrical continuity and programming without a computer, and included participation in a national contest. A post-activity questionnaire indicated that students found the club and its activities beneficial for their development, learning, and motivation.

Katniyon et al. (2023) studied the knowledge of educational robotics among pre-primary teachers in Plateau State using a descriptive survey design. The sample comprised 150 in-service ECCE teachers from the Federal College of Education Pankshin. Data was collected through a validated Robotics Knowledge Questionnaire, focusing on six aspects: awareness, knowledge, familiarity, and application. The findings revealed that pre-service teachers have low levels of awareness, knowledge, familiarity, and application of educational robotics, indicating they are unprepared to implement it in their STEM classrooms.

Arum (2019) advocates for integrating robotics into science education, emphasizing the need for curriculum planners to focus on robotic modeling in biological studies. This approach involves students in the exploration, design, and construction of robotic models, leading to enhanced understanding and improved learning outcomes. Arum notes that some organizations are already preparing students for international robotic tournaments, while other opportunities in this technology remain untapped. The paper outlines the steps for developing robotic models and their benefits in teaching and learning.

King and Uyouko (2024) conducted a study in Akwa Ibom State to investigate the impact of educational robots on learning experiences, focusing on active engagement and problem-solving among secondary school students. A correlational design was utilized, with a sample of 180 students selected using simple random sampling. Data was collected through a structured questionnaire, validated by an expert, and showed a high reliability coefficient of 0.89. Descriptive statistical analysis was employed to interpret the data. The findings indicated a high level of utilization of educational robots, particularly Ozobot, in schools, and concluded that educational robots significantly enhance learning by connecting theory with practice.

Ige and Omotuyole (2022) studied the perceived impact of robotics on early childhood education in Lagos State, focusing on 100 pupils, 50 teachers, and 100 parents from 10 private schools. The research utilized questionnaires and interview schedules, analyzing qualitative data with thematic analysis and quantitative data using t-Test and Pearson correlation. The findings indicated that most teachers and parents believed educational robotics positively impacts children's learning, despite some noted disadvantages. The hypothesis testing revealed differing perceptions between teachers and parents regarding the use of robotics in classrooms. The study concluded that the success of educational innovations depends on the perspectives of key stakeholders and recommended integrating educational robotics into public school curricula and increasing awareness among stakeholders.

The study by Nilüfer et al. (2022) systematically examines educational robotics and robots (ERR) with two main objectives: classifying research trends and gaps in ERR, and summarizing experimental findings related to ERR. A mixed-method approach, combining systematic mapping and systematic review, was employed to analyze 93 articles from SSCI-indexed journals. The results indicated that 40 of these articles lacked any learning theory, while 32 experimental studies were reviewed. The findings highlighted empirical support for some claims about ERR and identified research gaps requiring further theoretical and pedagogical exploration.

Lathifah et al. (2019) conducted a systematic literature review on the impact of robotics education in primary schools. The study highlights that robotics positively influences teaching and learning by engaging students and enhancing motivation. However, teachers reported that robotics activities can be time-consuming. Robotics education helps develop essential 21st-century skills through activities like assembling, programming, and testing robots. The Project-Based Learning model (PJBL) is identified as an effective approach for robotics education, fostering collaborative interactions between educators and students. The review indicates a need for broader keywords and contexts in future research, as the existing literature is somewhat limited.

Theinmoli et al. (2023) conducted a mini Systematic Literature Review (SLR) on educational robotics, which is used in both formal education and extracurricular activities to enhance student interest, engagement, and academic performance. The review covered articles from 2019-2023 across Scopus, Springer, and Science-Direct, following the PRISMA guidelines. Key findings indicated that Asia has conducted more research in this area, with survey questionnaires being the most common research method (40% of articles). Most studies focused on primary education, and the findings could inform future research, particularly regarding educational robotics for remedial students.

Arocena et al (2022) study on Robotics and Education was a systematic review analyzes the presence that technology, robotics specifically, has had on our educational system in recent years. Some keywords have been chosen, and screening has been carried out in the three most extensive databases about didactic and education: Education Resources Information Center, Scopus, and Web of Science chosen for being the most relevant in education sciences. Although among the most remarkable results, it was found that robotics is used as an individual skill developing tool. Its benefits as a teamwork promoting tool are not yet widely applied.

Alsoliman (2022) conducted a study on eighth grade students and their teachers using virtual platforms in five K–12 schools that incorporated physical robotics into STEM education. A qualitative phenomenological approach was employed, using focus groups with students and interviews with teachers. The study focused on the teaching and learning processes in STEM via virtual platforms and assessed their effectiveness. It found that virtual classrooms became widely accepted during the COVID-19 pandemic, prompting educators to enhance STEM skills through virtual robotics. While the benefits of virtual robotics motivated users, barriers included cultural norms and educational regulations related to virtual learning.

Smaragdi and Ilektra (2024) explored the connection between creativity and educational robots, focusing on how these robots can enhance creative thinking and computational skills through artificial intelligence. Their literature review covered studies from the past five years that examined the application of educational robots in STEM learning across various educational settings. Findings indicated that educational robots foster creativity-related skills such as reflection, collaboration, and innovation, making them valuable tools for modern educators. The study also suggests potential directions for future research and educational practices in this area.
Çakır et al. (2021) studied the impact of robotics and coding teaching on preschool children's problem-solving and creative thinking skills at a kindergarten in Amasia, Turkey, with 40 participants. The study utilized the "Problem Solving Skills Scale (PSSS)" and "Creative Thinking Skills Test" over four weeks, totaling 32 hours of classes. The experimental group used the We Do 2.0 Educational Robotics Kit, while the control group engaged in pen and paper activities. Results indicated a significant improvement in problem-solving skills and highlighted notable contributions to imagination, originality, and design factors in the experimental group compared to the control group.

CONCLUSION AND RECOMMENDATION

The integration of educational robotics into science education holds immense potential to transform traditional teaching methods and enhance student learning experiences. By providing hands-on, engaging, and interactive learning opportunities, robotics can spark students' interest in STEM subjects, develop critical thinking skills, and foster creativity and innovation. However, several challenges, including cost, teacher training, and access to technology, need to be addressed to fully realize the benefits of educational robotics. Future research should focus on investigating the long-term impact of robotics on student achievement, exploring innovative pedagogical approaches, and developing effective teacher training programs to support the implementation of robotics in classrooms. By overcoming these challenges and capitalizing on the opportunities offered by educational robotics, we can empower students to become active learners and future innovators.

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