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ORIGINAL

Educational Robotics in STEM Education: Approaches and Trends from an Educational Management Perspective

Robótica Educativa en Educación STEM: Enfoques y Tendencias desde la Perspectiva de la Gestión Educativa

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ABSTRACT

Introduction: educational robotics was consolidated as a key tool in STEM education (Science, Technology, Engineering, and Mathematics), by fostering technical, cognitive, and socio-emotional skills in students.
Objective: this study aimed to conduct a systematic review of approaches and trends in the use of educational robotics within STEM learning contexts, incorporating a perspective focused on educational management.
Method: a structured literature review methodology was applied, using recognized academic databases to identify relevant studies published between 2020 and 2024. The analysis included implementation strategies, technological tools, pedagogical models, reported benefits, and challenges.
Results: the findings showed that educational robotics strengthened computational thinking, problem-solving abilities, student motivation, and collaborative learning. However, persistent challenges were identified, such as unequal access to technology, the need for teacher training, and the lack of unified curricular standards, which posed significant issues for institutional management.
Conclusions: it was concluded that, in addition to constructivist and inquiry-based learning approaches, emerging trends included the integration of artificial intelligence and adaptive learning environments. The findings provided valuable insights for school leaders, educators, and researchers interested in incorporating educational robotics in STEM contexts from a strategic management perspective.

Keywords: Collaborative Learning; Digital Skills; Educational Management; Pedagogical Innovation; Computational Thinking; Educational Technologies.

RESUMEN

Introducción: la robótica educativa se consolidó como una herramienta clave en la educación STEM (Ciencia, Tecnología, Ingeniería y Matemáticas), al fomentar habilidades técnicas, cognitivas y socioemocionales en los estudiantes.
Objetivo: este estudio tuvo como objetivo realizar una revisión sistemática sobre los enfoques y tendencias en el uso de la robótica educativa dentro del contexto del aprendizaje STEM, incorporando una perspectiva desde la gestión educativa.
Método: se aplicó una metodología de revisión estructurada de la literatura, utilizando bases de datos académicas reconocidas para identificar estudios relevantes publicados entre 2020 y 2024. Se analizaron estrategias de implementación, herramientas tecnológicas, modelos pedagógicos, beneficios y desafíos reportados en los artículos seleccionados.
Resultados: los resultados evidenciaron que la robótica educativa fortaleció el pensamiento computacional, las habilidades de resolución de problemas, la motivación estudiantil y el aprendizaje colaborativo. Asimismo,

se identificaron obstáculos persistentes como el acceso desigual a la tecnología, la necesidad de formación docente y la ausencia de estándares curriculares, los cuales representaron retos clave para la gestión institucional.
Conclusiones: se concluyó que, además de los enfoques constructivistas y de aprendizaje basado en la indagación, emergieron tendencias como la integración de inteligencia artificial y entornos adaptativos. Los hallazgos aportaron elementos valiosos para directivos, docentes e investigadores interesados en integrar la robótica educativa en contextos STEM desde una perspectiva de innovación y gestión estratégica.

Palabras clave: Aprendizaje Colaborativo; Competencias Digitales; Gestión Educativa; Innovación Pedagógica; Pensamiento Computacional; Tecnologías Educativas.

INTRODUCTION

Educational robotics has been consolidated as a necessary tool in the teaching of STEM (Science, Technology, Engineering, and Mathematics) disciplines, promoting the development of technical, cognitive, and socioemotional skills in students.[1] Their integration into educational environments has improved computational thinking, problem-solving, and creativity and fostered collaborative work, essential skills for the 21st century.[2]

In recent decades, interest in STEM education has grown exponentially, driven by the need to train professionals capable of meeting the challenges of digital transformation and automation. Organizations such as the National Science Foundation (NSF) and the Institute of Electrical and Electronics Engineers (IEEE) have promoted research that explores innovative methodologies to strengthen learning in these areas.[3] In this context, educational robotics has been widely studied as a didactic resource that can improve academic performance and student motivation.

Despite technological advances, its implementation still faces limitations related to unequal access to resources, poor teacher training, and the absence of standardized curriculum policies.[4] These factors generate challenges and controversies around its viability on a large scale. Likewise, the diversity of pedagogical approaches to its application raises questions about the most appropriate models for integrating robotics into learning.[5]

From a historical perspective, robotics is a discipline that emerged in the 1960s. Due to limited access to knowledge and technology was initially linked to experts and engineers.[6]

Today, its inclusion in educational processes responds to the demands of an expanding digital culture, allowing students to develop competencies to face real problems and promote their active integration in society.[7]

Authors such as Pérez-Acosta et al.[6] conceive educational robotics as an active, interdisciplinary learning process mediated by electronic elements and software that promotes the development of applied skills in STEM fields and beyond. Studies highlighting how it improves abstraction and complex problem-solving[8] and strengthens motivation even in traditionally complex areas such as mathematics and physics.[9]

Technological progress has allowed educational robotics to evolve from basic construction kits to platforms integrating sensors, visual programming, and artificial intelligence, generating new possibilities for personalized learning. This has been reinforced by incorporating technologies such as machine learning and intelligent assistants, which favor adaptive environments.[10] However, they also debate ethics, privacy, and institutional management.

On the other hand, research by Aparicio Gómez[11] has shown that robotics can reduce the gender gap in access to STEM disciplines. At the same time, recent studies show that its inclusion from early stages helps to combat demotivation in these areas, developing students' skills such as algorithmic thinking, pattern abstraction, and process debugging.[12]

Given this scenario, this article aims to systematically review approaches and trends in educational robotics within the context of STEM education, also considering their implications for academic management. The analysis identifies the predominant pedagogical models, the technological tools employed, the implementation strategies, and the main benefits and challenges reported in recent scientific literature.

The scope of the study is limited to research published between 2020 and 2024 in recognized academic databases. The article is organized into six sections: Section 1 presents the introduction and contextualization of the problem; Section 2 presents the literature review related to educational robotics and its link to STEM learning; Section 3 describes the methodology used for the systematic review; Section 4 presents and analyses the results, integrating their discussion from an educational management perspective; section 5 presents the main conclusions and proposes future research directions; and section 6 states the source of funding for the study.

Literature review

Educational robotics has become a key pedagogical resource for strengthening teaching-learning processes, particularly in STEM (Science, Technology, Engineering, and Mathematics) education. Its implementation responds to the need to generate active learning environments that foster 21st-century skills, such as critical thinking, problem-solving, creativity, and teamwork.[13] From a theoretical perspective, educational robotics is based on constructivist and socio-constructivist approaches, where learning is built on interaction with the environment, collaboration between peers, and the resolution of real challenges. Pedagogical models such as project-based learning (PBL), problem-based learning (PBL), and discovery learning have been widely used to integrate robotics in the classroom.[14]

Regarding the disciplinary framework, STEM education seeks to develop transversal competencies that enable students to apply scientific and technological knowledge in practical situations. Robotics, by integrating electronics, mechanics, programming, and logic, aligns with the purposes of STEM education, allowing students to experiment with creative solutions to real-world challenges.[15]

Several studies have pointed out that using robotics in educational contexts improves academic performance, increases motivation, and favors students' active participation, especially in traditionally complex subjects. Moreover, educational robotics has been used to reduce the gender gap in STEM by generating more inclusive and egalitarian spaces.[16]

However, implementing robotics in the classroom presents significant challenges related to infrastructure, teacher training, and curriculum integration. The lack of technological resources, especially in rural or low-income areas, limits equitable access to these learning experiences.[17] Also, many teachers lack the technical and pedagogical preparation to effectively integrate robotics into their classes.[18]

In this context, educational management emerges as a key factor to ensure the sustainability and effectiveness of educational robotics strategies. Institutional decision-making, curriculum planning, investment in infrastructure, and teacher training must be considered from a managerial perspective to achieve meaningful implementation.[19] Finally, recent trends in the literature highlight the incorporation of emerging technologies such as artificial intelligence, augmented reality, and adaptive environments, which expand the possibilities of educational robotics and require new competencies from teachers and managers.[20]

METHOD

This systematic literature review on the use of educational robotics in STEM learning was carried out using a rigorous and structured methodological approach, following previous studies' guidelines.[21] The Rayyan tool managed and screened articles, facilitating the selection process and reducing bias through an anonymous review based on previously defined inclusion and exclusion criteria.

This review aims to examine the methodological and pedagogical strategies employed in educational robotics, identify their benefits and challenges in educational contexts, and analyze their contribution to the development of computational thinking, problem-solving, and motivation in STEM learning.

The methodological process was carried out in five main stages, which are presented in figure 1. These stages include planning the review, identifying sources, selecting studies, content analysis, and synthesis of findings. Each of these will be explained in detail in the following subsections to provide a clear overview of the procedure followed in this research

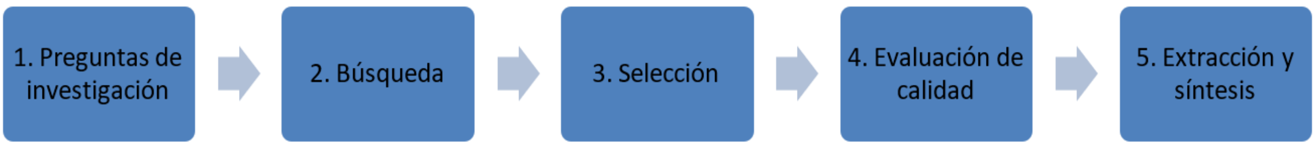

Figure 1. Stages of the systematic review methodological process

Research questions

The review was structured around six key questions formulated based on the PICO model and its variant PIPOH. It is widely used in systematic reviews to delimit the research elements precisely. These questions guided the analysis and allowed for a comprehensive view of the field:

This study aims to provide a comprehensive view of the impact of educational robotics on STEM learning through a systematic review of the scientific literature. To this end, a series of fundamental questions were formulated to structure the analysis of the most relevant publications in the field. These questions seek to identify predominant approaches, benefits, and challenges, as well as tools and methodologies used in integrating educational robotics within the STEM curriculum.From this premise, the following research questions guided the development of the study:

- RQ1: What are the predominant approaches in implementing educational robotics in STEM education?

- RQ2: What benefits and challenges have been reported in using educational robotics for learning STEM disciplines?
- RQ3: What tools and technology platforms are most frequently employed in educational robotics-based teaching?
- RQ4: What pedagogical strategies are used to integrate educational robotics into the STEM curriculum?
- RQ5: What are the current trends in research on educational robotics applied to STEM?
- RQ6: Are there methodological models or good practices identified in the literature for teaching STEM through educational robotics?

To ensure a structured approach to formulating these questions, we used the PICO (Population, Intervention, Comparison, and Outcomes) model with its variant PIPOH (Carrizo & Moller, 2018). This methodology is widely used in systematic reviews, as it allows us to precisely define the key elements of the research.

Table 1 presents the description of the criteria used in the construction of the analysis framework:

Table 1. Definition of concepts

Criteria	Description
Population	Teaching/learning in the context of STEM education with robotics educative
Intervention	Implementation of educational robotics, pedagogical strategies, technological tools and teaching/learning methodologies.
Results	Scientific publications (articles, books, conferences) addressing studies on STEM teaching/learning with educational robotics.
Professionals	Educators, researchers and specialists in STEM education and educational robotics.
Context	Academic and educational field at different levels of education.

Search

Search terms were established at this stage to identify relevant scientific articles and studies for the systematic review. These criteria are formulated to ensure comprehensive and up-to-date coverage of the literature related to educational robotics and its impact on STEM education. Priority was given to including rigorous, scientifically validated papers published in high-impact sources.

Key terms, along with their synonyms and related concepts, were defined to structure the search strategy. These terms were selected based on previous studies on educational robotics and STEM learning, ensuring a comprehensive collection of available information. Table 2 presents the main terms used in the query and the filters applied in the search process

Table 2. Term, synonyms and filters to compose the search string

Main terms	Synonyms/ Related
Educational Robotics	Learning Robotics, Robotics in Education
STEM Education	Science, Technology, Engineering, Mathematics Education
Computational Thinking	Problem-solving skills, Logical Reasoning, Algorithmic Thinking
Pedagogical Strategies	Teaching Methods, Instructional Approaches
Learning Outcomes	Academic Performance, Student Engagement

From these terms, the following search string was constructed to ensure that the most relevant studies were identified:

(‘Educational Robotics’ OR ‘Learning Robotics’ OR ‘Robotics in Education’)
AND (‘STEM Education’ OR ‘Science Technology Engineering Mathematics’)
AND (‘Computational Thinking’ OR ‘Problem-Solving Skills’ OR ‘Algorithmic Thinking’).

The search was carried out in scientific databases of international prestige, including IEEE Xplore, Scopus, Web of Science, ACM Digital Library, and ScienceDirect.

These databases were selected due to their broad coverage in education, technology, and engineering, which allowed the collection of relevant and methodologically sound studies for the analysis.

Selection

A detailed evaluation process was carried out to ensure the quality and relevance of the studies included in this systematic review. Key aspects such as title, keywords, abstract, introduction, background, state-of-the-art, methodology, results, and conclusions were analyzed during the article selection process.

To ensure that the selected studies were relevant and methodologically rigorous, inclusion and exclusion criteria were established to guide the literature filtering process:

Table 3. Number of primary studies obtained

Databases	Quantity
IEEE Xplore	15
ACM Digital Library	98
Scopus	285
Web of Sciencie	114
Total	512

Inclusion Criteria (I)

- I1: articles published within the last five (5) years to ensure up-to-date information.
- I2: the most recent version was selected in case of multiple publications derived from the same study.
- I3: only articles with access to the full text were included.

Exclusion Criteria (E)

- E1: technical papers, conference abstracts, or presentations without formal academic development were excluded.
- E2: only publications in English or Spanish were considered for ease of analysis.
- E3: studies that did not directly address educational robotics and its application in STEM education were excluded.

The selection process was carried out in three stages:

- Elimination of duplicate studies to avoid redundancies in the review.
- Reading the title and abstract to discard articles not meeting the inclusion criteria.
- Complete the text review to ensure the content's relevance and depth about the study objectives.

At the initial stage, 512 articles were identified through the search of the selected databases. After applying the selection criteria, the final number of papers considered for analysis was 58 studies. Table 3 presents the breakdown of the studies retrieved from each database.

Quality assessment

An assessment process based on seven key criteria was carried out to ensure the reliability and relevance of the studies included in this review. Firstly, the provenance of the sources was considered, prioritizing articles published in indexed journals and high-impact conferences. In addition, the relevance of the content was assessed, verifying that the studies were directly related to educational robotics and its integration into STEM education.

Another key aspect was the study's impact, which was analyzed by analyzing its citation level and recognition within the scientific community. The clarity of the research objectives was also reviewed, ensuring the questions were precise and relevant.

In addition, the study's context was examined, identifying whether the research focused on primary, secondary, higher education, or extracurricular settings. Methodological soundness was also assessed, considering the coherence and validity of the research design employed.

Finally, the data treatment and analysis rigor was analyzed, verifying that the results were presented with sufficient evidence and scientific substantiation. These criteria are aligned with the principles of planning, organization, and control in quality management[23] ensuring a rigorous selection of the most relevant scientific literature for this review.

In addition, the quality assessment process involved the detailed reading and analysis of the 58 selected studies. During this stage, several actions were taken, including eliminating duplicate articles, excluding documents that could not be downloaded, and strictly applying the previously defined inclusion and exclusion criteria. This procedure ensured that only the most relevant and scientifically validated studies were considered for analysis.

Table 4 summarizes the search and selection process, detailing the number of articles identified in each database, the number of papers eliminated because they were duplicates or did not meet the inclusion criteria, and the total number of relevant studies included in the review.

Table 4. Quality assessment in search and selection processes

Main term	Result search	Files duplicates	Archive Excluded	Archives relevant	Databases
Educational robotics and STEM	15	2	6	7	IEEE Xplore
Technologies and tools	98	10	58	20	ACM Digital Library
	285	70	157	20	Scopus
	114	15	89	11	Web of Science
Total	512	97	310	58	

RESULTS AND DISCUSSION

This section presents and discusses the findings from the systematic literature review on educational robotics in the STEM context. Various pedagogical approaches, benefits and challenges, technological tools, and emerging strategies have been identified that shape the current landscape of this line of research.

Predominant approaches to the implementation of educational robotics in STEM

The studies reviewed coincide in pointing out that educational robotics has been implemented with active and interdisciplinary pedagogical approaches, mainly Project Based Learning (PBL), Collaborative Learning, Problem-Based Learning (PBL), and gamification.[24] These methodologies favor the development of not only technical skills in students but also soft skills such as communication, teamwork, and creativity.

PBL stands out as the most widely used approach, allowing the integration of concepts from different STEM disciplines through projects focused on building and programming robots. Recent studies have shown that this approach improves students' motivation and critical thinking.[25] In a complementary way, collaborative learning reinforces the social dimension of the educational process, allowing the joint construction of knowledge[26] which coincides with the current trend of promoting peer learning in technological contexts.

PBL, on the other hand, encourages real-world problem-solving through the application of technical knowledge, increasing students' autonomy and their ability to transfer what they learn to authentic contexts.[27] Gamification is a complementary approach that encourages active participation by introducing game mechanics, significantly increasing motivation and engagement.[28]

These approaches evidence a transition from traditional methods to more dynamic and learner-centered models, supporting the effectiveness of robotics as a mediator of active learning in the STEM area.

Benefits and challenges in the implementation of educational robotics in STEM

The benefits of educational robotics in STEM are multiple and widely documented. Exposing stuents to programming logic and algorithmic design processes highlights its role in developing computational thinking. Furthermore, its positive effect on student motivation has been proven, especially at educational levels where interest in science wanes.[12]

Likewise, educational robotics boosts creativity and innovation in problem-solving, offering spaces for experimentation and design in which students propose original solutions.[29] These characteristics position robotics as an ideal tool for promoting key 21st-century skills in school contexts.

However, these benefits are limited by important challenges. One of the most recurrent is the lack of teacher training in educational robotics. The literature shows that many educators do not have sufficient technical and methodological training, which affects the quality of implementation. This finding reflects the need to strengthen initial and continuous teacher training in digital and pedagogical skills related to robotics.

Another obstacle identified is the scarce inclusion of robotics in official curricula, which hinders its systematic integration. The lack of institutional guidelines and resistance to methodological change prevent robotics from establishing itself as a sustained practice.[10] In addition, a marked inequality in access to technological resources persists between institutions, especially between rural and urban areas, which deepens the digital divide and limits equity in STEM education.[2]

Technological tools and platforms used

The systematic review identified the technological tools and platforms most commonly used in STEM education with educational robotics. These tools facilitate the acquisition of programming, electronics, and automation skills, offering students interactive and dynamic environments for problem-solving.

One of the most widely used resources in STEM education with robotics is visual programming platforms, such as Scratch, Blockly, and MakeCode.[30]

These tools allow students to program robots using graphical blocks instead of traditional lines of code, which facilitates the understanding of algorithmic and logical concepts from an early age.[31] In addition, these platforms encourage creativity and experimentation, as students can develop customized projects and intuitively iterate on their designs.

Educational robotics kits represent another key category in STEM education. Among the most commonly used are LEGO Mindstorms, Arduino, Raspberry Pi, and VEX Robotics. These kits provide physical components, such as sensors, motors, and electronic boards, which students can assemble and program to build functional robots. Robotics kits encourage hands-on learning and the development of engineering skills, as they allow students to tackle real problems and apply knowledge of electronics, mechanics, and programming in an integrated way.[32] Moreover, the versatility of these kits allows their use at different educational levels, from primary to university, adapting to different degrees of complexity.

In addition, several robotics simulation platforms, such as Tinkercad, VEXcode VR, and Robot Virtual Worlds, have been identified, allowing students to program and test robots in virtual environments without needing physical hardware. These platforms are beneficial in contexts where access to robotics kits is limited, as they provide learning experiences similar to those of programming and controlling physical robots; the use of robotics simulators improves accessibility to STEM education and allows students to experiment with robot programming in a safe environment without high costs.[33] In addition, simulators facilitate debugging errors and optimizing algorithms before implementing programs on real robots.

Finally, the studies analyzed highlight the use of traditional programming languages, such as Python, C++, and JavaScript, in teaching educational robotics. These languages are widely used in academic and professional environments, allowing students to develop advanced programming skills with practical applications in the technology industry. According to Garcia Rodriguez et al.[34] Python is especially popular in robotics education due to its simple syntax and compatibility with platforms such as Raspberry Pi and Arduino, which facilitates the transition from visual programming to text-based coding languages.[35]

Pedagogical strategies in the integration of educational robotics in STEM

The implementation of educational robotics in STEM has been accompanied by various pedagogical strategies that seek to maximize learning and the acquisition of key competencies in science, technology, engineering, and mathematics. These strategies allow not only the appropriation of technical knowledge but also the development of transversal skills such as critical thinking, creativity, and teamwork.[33]

One of the most prominent strategies in integrating educational robotics is using active methodologies, particularly challenge-based learning. This methodology poses real or simulated problem situations in which students must design, build, and program robots to solve them; according to Pacheco et al.[20] challenge-based learning favors students' motivation and autonomy by involving them in projects where they apply STEM knowledge in meaningful contexts. In addition, it fosters the development of computational thinking and problem-solving skills, as students must analyze, devise solutions, and optimize their designs iteratively.

Another key strategy is the implementation of blended learning environments, which combine face-to-face sessions with virtual activities. This modality allows for greater flexibility in teaching educational robotics, as students can develop part of the learning in digital environments, using simulators and online programming platforms, and then apply this knowledge in face-to-face activities with robotics kits. The blended model facilitates the personalization of learning and improves access to technological resources, especially in contexts where physical infrastructure is limited. Combining hands-on and virtual experiences allows students to strengthen their programming and problem-solving skills more effectively.

Formative assessment and self-assessment through digital portfolios is another relevant strategy in teaching educational robotics. In this approach, students document their learning process through digital records, including designs, programming codes, reflections, and evidence of their robotic projects. The use of digital portfolios not only allows teachers to track students' progress in more detail but also fosters self-regulation of learning by having students reflect on their achievements and areas for improvement.

Implementing educational strategies that guide the student to acquire better learning is an effective way to achieve adequate pedagogical development. Nowadays, the constructivist paradigm seems to be a tool that

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helps the teacher develop indisputable profiles and competencies for 'Learning by doing. ' It has been shown that the best way to 'not forget' and acquire a better understanding of something is achieved when it is built up gradually as opposed to something that is visualized globally.[27]

For this reason, teaching and implementing educational robotics in the classroom have acquired great importance in developing essential skills such as logical thinking, critical thinking, and problem-solving by using creativity. Education experts have shown that integrating educational units into the curriculum allows students to acquire and interact with abstract concepts tangibly, observing their behavior in different situations. Additionally, implementing this strategy facilitates understanding complex issues, such as the different concepts necessary for creating technological solutions or the design of engineering schemes, which, through the manipulation of robots, become more motivating and easier to assimilate.

The use of robotic elements in the classroom encourages active and collaborative learning, allowing each member to work as a team and investigate strategies to design, build, and program robots that perform specific tasks necessary to solve a previously analyzed difficulty. This technique helps develop technical and soft skills such as communication, teamwork, and leadership. Moreover, the ease of adaptation of educational robotics to different educational levels, including primary and university, strengthens and helps teachers in their training work by making many challenges suitable for each stage of learning

Current trends in STEM educational robotics research

Research in educational robotics within the STEM field has experienced significant growth in recent years, driven by technological advances and new pedagogical methodologies. One of the most relevant trends is integrating artificial intelligence (AI) in educational robots, which improves interaction with students and adapts learning experiences to their individual needs. Recent studies have shown that the use of AI in educational robotics not only facilitates the personalization of learning but also fosters the development of advanced cognitive skills, such as critical thinking and problem-solving.

Another emerging trend is using social and humanoid robots in educational settings. Research has shown that these robots can play a key role in teaching, as they offer more natural and motivating interactions for students, encouraging active learning and participation in STEM activities.[4] Humanoid robots have been used in various disciplines, from teaching programming to developing social and emotional competencies in the classroom.[5]

Furthermore, research has gained ground on integrating augmented reality (AR) and virtual reality (VR) in educational robotics. These technologies allow the simulation of complex environments and situations, facilitating experiential learning and experimentation in scenarios that are difficult to replicate physically. Several studies have reported that using AR and VR in STEM education increases students' motivation and improves their understanding of abstract concepts and their ability to solve problems in real contexts.

Finally, a key aspect of current trends is the expansion of inclusion programs that seek to bring educational robotics to communities with limited access to technology.[29] The implementation of initiatives that promote equity in STEM education has proven to be critical in bridging the digital divide and encouraging the participation of groups historically underrepresented in these disciplines. Recent research has highlighted the importance of providing access to technological tools and resources in schools with fewer opportunities, as this not only improves students' learning but also strengthens their interest in science and technology careers.[32]

The findings of this systematic review reflect the growing importance of educational robotics in STEM education. Evidence suggests that its implementation favors the development of technical and transversal skills essential in the digital age. However, despite the reported benefits, there are still barriers to access to technology, teacher training, and curriculum standardization.

Further research is needed on effective pedagogical models and implementation strategies to maximize the impact of educational robotics in STEM. In addition, it is recommended that public policies and funding programs be strengthened to reduce the digital divide and ensure equitable access to these technologies.[36]

CONCLUSIONS

The systematic review shows that educational robotics has been consolidated as an effective pedagogical strategy for strengthening STEM skills at various educational levels. The predominant methodological approaches, such as project-based learning (PBL), collaborative learning, problem-based learning (PBL), and gamification, have shown positive results in motivation, active participation, and meaningful understanding of scientific and technological concepts by students.

Multiple benefits of their implementation are also highlighted, including the development of computational thinking, creativity, innovation, and the ability to solve real problems. These achievements are closely linked to the possibility of working with interactive technologies that allow for direct experimentation, both individually and collectively.

However, important challenges have also been identified, such as teacher training, the scarce curricular inclusion of educational robotics, and the technological gap between educational institutions. These obstacles limit the scope and sustainability of robotics programs in diverse educational settings.

The technological tools used, such as visual programming platforms (Scratch, Blockly), robotics kits (LEGO, Arduino, VEX), and virtual simulators (Tinkercad, VEXcode VR), play a fundamental role in the effective implementation of these strategies, facilitating the appropriation of technical knowledge and transversal skills in students.

In summary, educational robotics in STEM represents an innovative teaching medium and a transformative opportunity to face the challenges of the 21st century in scientific and technological education. However, its consolidation as a transversal strategy depends on institutional will, investment in infrastructure, and, above all, the strengthening of teaching skills.

BIBLIOGRAPHIC REFERENCES

1. García DJM, Acero Ordóñez OL. La robótica educativa: una interdisciplina didáctica integradora para la enseñanza. p. 1-23. doi: 10.36737/01230425.n48.3160

2. Zambrano EC. Implementación de la robótica educativa en el currículo escolar: Experiencias y perspectivas. Revista Ingenieria Global. 2023;2:1-12. doi: 10.62943/rig.v2n2.2023.63

3. Useche Gutiérrez G, Vargas Guativa J. Una revisión desde la epistemología de las ciencias, la educación STEM y el bajo desempeño de las ciencias naturales en la educación básica y media. Revista Temas. 2019;13:109-21. doi: 10.18359/ravi.586601

4. Zorrilla-Puerto J, Lores-Gómez B, Martínez-Requejo S, Ruiz-Lázaro J. El papel de la robótica en Educación Infantil: revisión sistemática para el desarrollo de habilidades. Revista Interuniversitaria de Investigación en Tecnología Educativa. 2023;188-94. doi: 10.6018/riite.586601

5. Valero Carvajal DA, Orozco Isaza JE, Córdoba Puerto JN, Noreña Hemelberg OS, Gómez Alarcón MA, Jinete Gómez MA, et al. Algoritmos para el procesamiento de imágenes implementados en el Robot Humanoide InMoov. Revista EIA. 2021;18. doi: 10.24050/reia.v18i36.1495

6. Pérez-Acosta GX, Mendoza-Moreno MÁ. Robótica educativa: propuesta curricular para Colombia. Educación y Educadores. 2021;23:577-95. doi: 10.5294/edu.2020.23.4.2

7. Cuchillac VM. La enseñanza de IoT como estrategia para desarrollar competencias técnicas para la Industria 4.0. Realidad y Reflexión. 2023;57:15-38. doi: 10.5377/ryr.v1i57.16694

8. Delgado C. Didactic strategies to strengthen creative thinking in the classroom. A meta-analytic study. Revista Innova Educación. 2021;4:51-64. doi: 10.35622/j.rie.2022.01.004.en

9. Rosero Calderón OA. La Robótica Educativa: Potenciando el pensamiento matemático y habilidades sociales en el aprendizaje. Emerging Trends in Education. 2024;7:129-44. doi: 10.19136/etie.a7n13.6040

10. Tomalá De La Cruz MA, Mascaró Benites EM, Carrasco Cachinelli CG, Aroni Caicedo EV. Incidencias de la inteligencia artificial en la educación. RECIMUNDO. 2023;7:238-51. doi: 10.26820/recimundo/7.2.238-251

11. Aparicio Gómez WO. La Inteligencia Artificial y su Incidencia en la Educación: Transformando el Aprendizaje para el Siglo XXI. Revista Internacional de Pedagogía e Innovación Educativa. 2023;3:217-30. doi: 10.51660/ripie.v3i2.133

12. Caballero-González YA, García-Valcárcel A. ¿Aprender con robótica en Educación Primaria? Un medio de estimular el pensamiento computacional. Education in the Knowledge Society. 2020;21:15. doi: 10.14201/eks.21443

13. Mesa Pinto FH. Plataformas de Simulación como Didáctica para el Proceso Enseñanza-Aprendizaje de la Robótica Educativa. Scientific Journal T&E. 2025;1:143-65. doi: 10.48204/3072-9653.6885

14. Ferrada C, Díaz-Levicoy DA. Perspectiva del enfoque STEM y Robótica en las aulas de educación Primaria vista por maestros de 5o y 6o grado. 2025.

15. Calabrés Veroes AM. Motivación e interés por la tecnología: El papel de la robótica en educación. Prohominum. 2025;7:113-22. doi: 10.47606/ACVEN/PH0336

16. Trapero-González I, Aznar-Diaz I, Ramos Navas-Parejo M, Romero-Rodríguez JM. Examinando las influencias sociodemográficas en la comprensión y preparación de los maestros en formación para enseñar STEM. 2025.

17. Molano García DJ, Acero Ordóñez OL. La robótica educativa: una interdisciplina didáctica integradora para la enseñanza. Educación y Ciudad. 2024;48:e3160. doi: 10.36737/01230425.n48.3160

18. Martínez Cardero D. Innovación pedagógica en la enseñanza de la Inteligencia Artificial. Revista Internacional de Pedagogía e Innovación Educativa. 2025;5:47-76. doi: 10.51660/ripie51226

19. Pincay Mendoza YA, Marcillo Salazar VC, García Constante VV, Espinoza Cesme AG, Morán Holguín AM, Veloz Santa Cruz GA. Decisiones gerenciales automatizadas: Integrando big data y machine learning. Ciencia y Desarrollo. 2025;28:357. doi: 10.21503/cyd.v28i1.2830

20. Álvarez, Peña ZI, Aragundi Rosero MJ, Pacheco Góngora RD. Augmented reality and virtual reality in the classroom: Potential and challenges. 2025;3.

21. Quispe AM, Hinojosa-Ticona Y, Miranda HA, Sedano CA. Serie de Redacción Científica: Revisiones Sistemáticas. Revista del Cuerpo Médico Hospital Nacional Almanzor Aguinaga Asenjo. 2021;14:94-99. doi: 10.35434/rcmhnaaa.2021.141.906

22. Carrizo D, Moller C. Estructuras metodológicas de revisiones sistemáticas de literatura en Ingeniería de Software: un estudio de mapeo sistemático. Ingeniare Revista chilena de ingeniería. 2018;26:45-54. doi: 10.4067/S0718-33052018000500045

23. Amaya Pingo PM, Felix Poicon ECL, Rojas Vargas S, Diaz Tito LP. Gestión de la calidad: Un estudio desde sus principios. Revista Venezolana de Gerencia. 2020;25:632-47. doi: 10.37960/rvg.v25i90.32406

24. Domènech-Casal J, Lope S, Mora L. Qué proyectos STEM diseña y qué dificultades expresa el profesorado de secundaria sobre Aprendizaje Basado en Proyectos. Revista Eureka sobre enseñanza y divulgación de las ciencias. 2019;16:1-16. doi: 10.25267/Rev_Eureka_ensen_divulg_cienc.2019.v16.i2.2203

25. Quevedo-Benítez KP, Rodríguez-Velandia DA, Moran-Borbor RA, Niño-Vega JA, Fernández-Morales FH. Fortalecimiento de competencias en innovación tecnológica: una estrategia didáctica apoyada en el Aprendizaje Basado en Proyectos. AiBi Revista de Investigación, Administración e Ingeniería. 2024;12:47-54. doi: 10.15649/2346030X.3657

26. Chiliquinga Masaquiza RR, Rodríguez Arce KL, Luje Pozo DI, Pucha Gualoto OI. Desarrollo de habilidades del siglo XXI a través de la educación STEM. Revista Imaginario Social. 2024;7. doi: 10.59155/is.v7i2.191

27. Panskyi T, Rowińska Z. A Holistic Digital Game-Based Learning Approach to Out-of-School Primary Programming Education. Informatics in Education. 2021. doi: 10.15388/infedu.2021.12

28. Berciano-Alcaraz A, Salgado-Somoza M, Jiménez-Gestal C. Alfabetización computacional en educación infantil: Dificultades y beneficios en el aula de 3 años. Revista Electrónica Educare. 2022;26:1-21. doi: 10.15359/ree.26-2.15

29. Gamito Gomez R, Hermoso Larzabal E, Leon Hernandez I, Bilbao Antia L. Aprendizaje-Servicio para acercar la robótica educativa a las personas con parálisis cerebral y promover las competencias docentes. Edutec Revista Electrónica de Tecnología Educativa. 2021;78:114-30. doi: 10.21556/edutec.2021.78.2213

30. Morán-González M, Gallegos-Macías MR. Plataformas tecnológicas y su aporte al aprendizaje en línea para la asignatura de matemática. Revista Científica Multidisciplinaria Arbitrada Yachasun. 2021;5:119-39. doi: 10.46296/yc.v5i9edespsoct.0115

31. Naval FM, Vives-Rego J. Precisiones interdisciplinares y conceptuales de los términos cyborg, clon humano y robot.

32. Silva Pérez EJ, Guachamboza Ramirez AM, Guía C. Brechas y Retos en la Innovación Educativa: Un Análisis Bibliográfico. Revista Tecnopedagogía e Innovación. 2024;3:37-57. doi: 10.62465/rti.v3n2.2024.106

33. Ferrada C, Carrillo-Rosúa FJ, Díaz-Levicoy D, Silva-Díaz F. La robótica desde las áreas STEM en Educación Primaria: una revisión sistemática. Education in the Knowledge Society. 2020;21:18. doi: 10.14201/eks.22036

34. García Rodríguez A. Enseñanza de la programación a través de Scratch para el desarrollo del pensamiento computacional en educación básica secundaria. Academia y Virtualidad. 2022;15:161-82. doi: 10.18359/ravi.5883

35. Pinargote-Zambrano JJ, Lino-Calle VA, Vera-Almeida BJ. Python en la enseñanza de las Matemáticas para estudiantes de nivelación en Educación Superior. MQRInvestigar. 2024;8:3966-89. doi: 10.56048/MQR20225.8.3.2024.3966-3989

36. Espinosa Cevallos PA. Evaluación de programas de educación STEM en diferentes niveles educativos. Nexus Research Journal. 2024;3:54-64. doi: 10.62943/nrj.v3n1.2024.81

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CONFLICT OF INTEREST

Authors declare that there is no conflict of interest.

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