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Implementation of Integrated STEM Learning in Educational Robotics towards 21st Century Skills: A Systematic Review

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Abstract

Science, technology, engineering and mathematics (STEM) has become a frequently discussed topic in education in recent years. This study aims to categorize research findings related to Educational Robotics through Integrated STEM Learning towards 21st century skills in 2019-2024. In its review, this study used PRISMA systematic review. Paper searches were conducted on Scopus, ScienceDirect, and DOAJ databases on December 2023-January 2024. A total of 30 articles to review. The review in this study made it possible to categorize the Implementation of Integrated STEM in the form of Educational Robotics towards the development of 21st century skills in two categories. The first category was based on the improvement of students' abilities, the learning and teaching process, and the relationship with 21st century skills. The second category was based on the evaluation of STEM integrated with Educational Robotics to support 21st century skills. The results from the first category had a strong influence in improving students' abilities, the learning and teaching process, and the relationship with 21st century skills. From the second, it was determined that there is a need for the development of methods in learning educational robotics and it is important to support 21st century skills.

Introduction

STEM education is becoming increasingly important in preparing future generations for the dynamic changes in various fields of life (Bardoe et al., 2023). In the midst of an ever-evolving technological revolution, a deep understanding of science, technology, engineering and math provides a solid foundation to face future challenges. The ability to adapt and innovate gained through STEM education plays a key role in solving increasingly complex problems in the modern era (He et al., 2023).

STEM education not only aims to provide conceptual knowledge, but also promotes critical and creative thinking skills (Yalçın, 2022). Students are encouraged to analyze deeply (Vooren et al., 2022), explore different ideas (Grimalt-Álvaro et al., 2022), as well as come up with innovative solutions. Having the capacity for innovative thinking is crucial when addressing intricate issues that emerge.. The ability to work collaboratively and in teams is integral to STEM education (Zhou et al., 2022). Students are prompted to work together in cross-disciplinary groups, pooling their expertise and capabilities to accomplish assignments encompassing diverse STEM domains. (Kilty & Burrows, 2022). Effective teamwork is key to producing the best solutions in real-world situations (Smith et al., 2022).

STEM education provides space for students to express creativity and innovation (Weng et al., 2022). In an environment that supports experimentation and problem-solving, students are encouraged to design solutions to real-world problems (Wingard et al., 2022). This contributes to the creation of new innovations, technologies and ideas that can bring positive change to society (Atasoy et al., 2023). Amidst the transformation of jobs by technological developments, STEM education offers a solid foundation for students to enter the ever-changing job market (Hynes et al., 2023). The abilities gained from STEM education give students an edge in preparing for challenges in various career fields that rely on STEM skills (Skrentny & Lewis, 2022). In the domain of STEM education, a significant gap is evident, primarily concerning the lack of interdisciplinary integration (Hamad et al., 2022). Curricula tend to teach science, technology, engineering, and mathematics in isolation, impeding the development of a holistic understanding. Overcoming this challenge requires the development of more integrated STEM curricula, emphasizing interdisciplinary connections and encouraging students to apply their knowledge in real-world problem-solving.

The swift expansion of technology has triggered a notable transformation in education, particularly concerning the principles of STEM (Science, Technology, Engineering, and Mathematics). (Xu & Zhou, 2022). The incorporation of Educational Robotics into the STEM curriculum represents a recent innovation that is reshaping our learning methods. (Darmawansah et al., 2023). Educational Robotics offers a practical way for students to apply STEM concepts in a real-world context (Joventino et al., 2023) . It allows students to learn in an interactive and immersive way, expanding their understanding of scientific concepts as well as the application of technology in everyday life.

Within the context of STEM education, Educational Robotics offers chances for students to cultivate their abilities in technology, as well as problem-solving and critical thinking capabilities. (Liu et al., 2022).Through the design, programming and operation of robots, students not only acquire theoretical knowledge, but also apply it in practical situations (Eguchi et al., 2023). This not only builds a strong foundation in STEM, but also taps into students' potential to think creatively (Chevalier et al., 2020) and collaborate in solving complex tasks (Kerimbayev et al., 2023). Educational Robotics also facilitates cross-disciplinary learning (Chang & Chen, 2020), integrating concepts from various STEM fields (Hsu et al., 2022). Students have the opportunity to develop a comprehensive comprehension of the interconnectedness of science, technology, engineering, and mathematics within the realm of constructing and operating robots. (Screpanti et al., 2022). This not only enhances their understanding of the material, but also provides a more comprehensive picture of how the concepts work together.

Educational Robotics within the STEM framework also contributes to nurturing skills relevant for the 21st century (Gratani & Giannandrea, 2022). In addition to technical skills, students also develop adaptability (Coufal, 2022), critical thinking (Kálózi-Szabó et al., 2022), teamwork and creativity (Valls Pou et al., 2022). The practical application of STEM concepts through robotics provides an opportunity for students to acquire skills relevant to future demands, preparing them for wider challenges in the real world (Christopoulos et al., 2022). Utilizing Educational Robotics within STEM education not just offers hands-on practice but also nurtures an inherent drive within students to engage more deeply in STEM learning (Üçgül & Altıok, 2022). Direct interaction with robots encourages student interest and engagement in learning, making the learning process more interesting and fun (Tselegkaridis & Sapounidis, 2022). This can help in overcoming learning barriers and encourage students to explore deeper in the STEM world. The implementation of educational robotics faces a significant challenge related to accessibility and inclusivity. Unequal distribution of robotic tools and resources can lead to disparities in learning opportunities, widening educational gaps. Overlooking diverse abilities in designing robotics activities may exclude certain learners. Bridging this gap requires efforts to ensure accessibility for all students, addressing affordability issues, providing teacher training, and fostering an inclusive environment, ultimately enhancing the potential of educational robotics for a more equitable learning experience.

21st century skills are becoming an important cornerstone in education, especially when educational robotics is integrated into the STEM curriculum (González-Pérez & Ramírez-Montoya, 2022). The development of these skills is not only about understanding technology, but also about adaptability, critical thinking, collaboration and creativity required in an ever-evolving world (Valls Pou et al., 2022). Through robotics education, students not only gain technical expertise but also become equipped to confront the complexities of a rapidly evolving contemporary society. (Lavicza et al., 2022).

The importance of 21st century skills in STEM education integrated with robotics lies in the ability of students to adapt quickly to ever-evolving technological changes (Mácha et al., 2023). These skills allow students to continuously learn, innovate and develop their critical thinking in solving complex problems. This is important, as it prepares them to face future challenges that may not be obvious today. In addition, the 21st century skills acquired through robotics learning also build students' collaboration abilities (Coşkun & Filiz, 2023). In a STEM environment, students learn to work in multidisciplinary teams, combining different skill sets to achieve a common goal (Liston et al., 2023). This not only enhances their understanding of various disciplines, but also hones the ability to work in teams, communication and leadership skills required in the professional world (Hiğde & Aktamış, 2022).

Creativity is also an important aspect developed through robotics learning in the STEM approach (Eroğlu & Bektaş, 2022). Students are motivated to explore beyond conventional boundaries, discover inventive answers, and craft imaginative endeavors through the application of their acquired STEM expertise. (Wannapiroon & Pimdee, 2022). These skills are crucial in facing future challenges that require unique and innovative solutions (Amran et al., 2022). The significance of these 21st-century competencies within the framework of STEM education merged with robotics not only readies students for the academic sphere but also equips them for real-world applications (González-Pérez & Ramírez-Montoya, 2022). These skills enable students to become adaptive, creative, and change-ready individuals in an ever-changing work environment that demands relevant skills. The implementation of 21st-century skills within the education system often encounters conspicuous disparities. There exists incongruity in the integration of skills such as critical thinking, creativity, collaboration, and digital literacy among schools and regions. To address these disparities, concerted efforts are necessary to develop a more uniform approach, including enhanced teacher training and the seamless integration of 21st-century skills into the national curriculum.

The collective implementation of educational robotics, 21st-century skills, and STEM education confronts multifaceted challenges. In the realm of educational robotics, the significant hurdle lies in ensuring accessibility and inclusivity, as disparities in resource distribution can widen educational gaps. Efforts to bridge this gap require addressing affordability issues, providing teacher training, and fostering an inclusive learning environment. Similarly, the integration of 21st-century skills faces conspicuous disparities, emphasizing the need for a more uniform approach. Enhanced teacher training and seamless integration into the national curriculum become imperative to address these disparities effectively. In STEM education, a pronounced challenge is evident in the lack of interdisciplinary integration, hindering the development of a holistic understanding. Overcoming this challenge necessitates the creation of integrated STEM curricula, emphasizing interdisciplinary connections and encouraging practical application of knowledge in real-world problem-solving scenarios.

Method

This research endeavors to recognize and categorize research discoveries associated with the fusion of STEM Learning and Robotics Education within the scope of fostering 21st-century skill development from 2019 to 2024. This research was conducted with a focus on the influence and impact of the implementation of such integration. The methodology of this research refers to the PRISMA (Page et al., 2022) guidelines for conducting systematic reviews. The database selected for information retrieval is Scopus indexed articles, ScienceDirect, and DOAJ. The complete process is described visually in Figure 1.

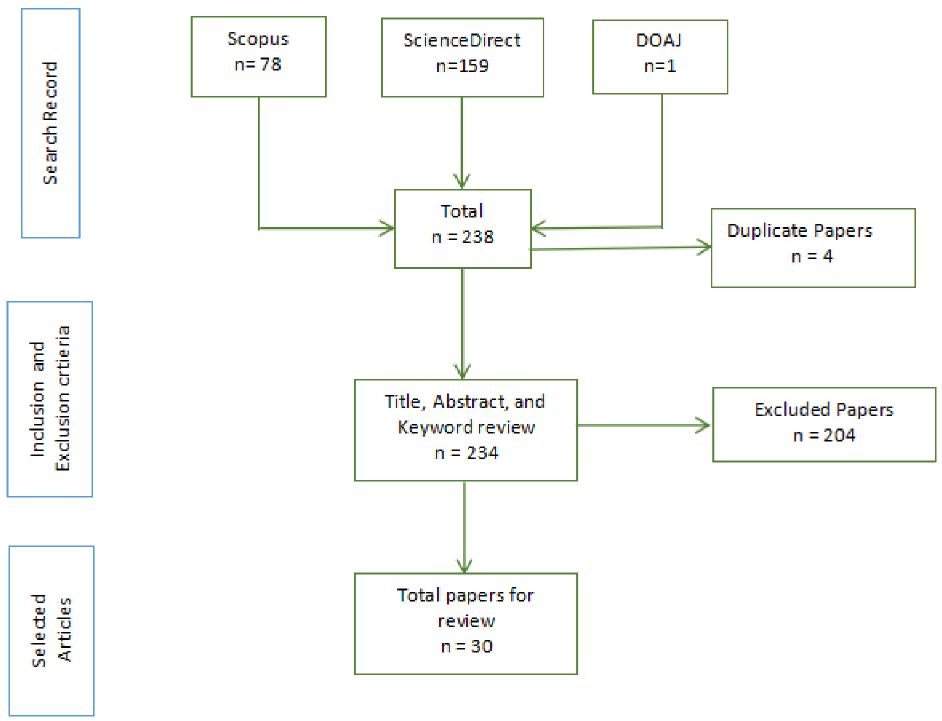

Figure 1. Flow Chart

The study involved modifications made to the equations and filters within individual databases, elaborated in Table 1. Initially, 958 articles pertaining to the integration of STEM with Educational Robotics were discovered, whereas 1,234 articles concerning the fusion of STEM with 21st Century Skills were identified through the initial search. These articles were then combined into one topic on STEM integration related to Educational Robotics towards 21st century skills, totaling 238 articles with full-text studies. Afterward, four identical research works were removed, and the standards for inclusion and exclusion, detailed in Table 2, were used to evaluate 234 articles by reviewing their titles, abstracts, and keywords. After the selection process, 30 articles were left that met the inclusion and exclusion criteria for further reading.

Table 1. Search Equations and Filters

Database	Search equation	Applied Filters
Scopus	integrated AND stem AND with AND educational AND robotic AND on AND 21st AND century AND skills	Publication status: final. Type of document: article. Open Access. From 2019 to 2024.
DOAJ	Integrated AND stem AND educational AND robotic	Type of document: article. Open Access. From 2019 to 2024.
ScienceDirect	integrated AND stem AND with AND educational AND robotic AND on AND 21st AND century AND skills	Publication status: final. Type of document: article. Open Access. From 2019 to 2024.

Table 2. Inclusion and Exclusion Criteria

Inclusion criteria	Exclusion criteria
The STEM acronym or Educational Robotics Words must be in the title, abstract, or keywords.	The STEM or Educational Robotics Words acronym is not present in the title, abstract, or keywords.
This study requires further development, whether in full or in part, by integrating educational robotics content associated with 21st-century skills.	Unconnected to Educational Robotics and skills relevant to the 21st century.
The research ought to take the shape of an empirical document and a systematic review, released within the period from 2019 to 2024.	A systematic review or meta-analysis. Published in other periods.

Results and Discussion

This research is assisted by division through a concept matrix. The concept matrix is a chart containing classifications that help the author to map the research concisely and clearly so as to obtain maximum review results. This research focuses on two research questions, namely the influence of STEM integrated with robotics education and evaluation of the benefits of STEM integrated with robotics education on 21st century skills. In the end, the classification was found in 30 selected articles based on the search by determining the research results, research targets, research insights, and subthemes of the research grouping as in Figure 2, for more detail in the notes.

Topic	Implementation of Integrated STEM Learning in Educational Robotics towards 21st Century Skills : A Systematic Review					Keywords:	#article in ScienceDirect		
RQ (Research Question)	How is the Application of Integrated STEM Learning in Educational Robotics towards 21st Century Skills?						Range: anytime	Range: 2019-2023	Range: 2021 - 2023
Guiding Question 1	What are the benefits of Integrated STEM learning in Robotics education at school?					Integrated STEM on Educational Robotic	1901 (per Nov 18)	910	609
Guiding Question 2	How does Integrated STEM learning affect 21st century skills?					Integrated STEM on 21st Century Skills	2727 (Per Nov 18)	1142	823
		Concepts						Theorizing	
Article	Method	sample size	Level of Education	Participant/subject	0	finding	Answer to RQ	insights	Synthesis
Yang, F. C. O., Lai, H. M., & Wang, Y. W.	Quasi-Experimental Design	75	First Year University	Students		The results showed that students who used AR Bot had higher enjoyment of learning, algorithm design skills, and algorithm efficiency skills but not higher problem decomposition skills and academic achievement than students who used Scratch. Enjoyment of learning led to higher problem decomposition, algorithm design, and algorithm efficiency skills but not academic achievement. Problem decomposition and algorithm design skills, but not algorithm efficiency skills, led to academic achievement. The theoretical and practical implications of the proposed tool and other CT tools in programming education are discussed.	1	students who used AR Bot had higher enjoyment of learning, algorithm design skills, and algorithm efficiency skills but not higher problem decomposition skills and academic achievement than students who used Scratch	Evaluation of Integrated STEM in Educational Robotics
Ching, Y. H., & Hsu, Y. C. (2023). Educational Robotics for Developing Computational Thinking in Young Learners: A Systematic Review. TechTrends, 1-12.	Literature Review	22	pre-kindergarten to 6th grade	Literature		The findings revealed that using robotics activities to develop CT has mostly been studied in the formal education settings with the duration of robotics curricular activities ranging from 80 minutes to 24 hours. The five CT skills studied most often include Sequencing, Conditionals, Loops, Debugging, and Algorithmic Thinking. The different versions of LEGO Mindstorms are the most frequently adopted robotic kits in the examined studies. The most frequently adopted learning and instructional strategies in the robotics activities include collaborative learning, project-based learning, and embodied learning. This paper identified and discussed developmentally appropriated CT skills, robotics kits, and pedagogical approaches suitable for supporting CT development in young learners. The findings can guide educators and instructional designers for future robotics activity design and development endeavors. This paper also identified gaps in the current research and recommended directions for advancing research in adopting robotics to develop CT in young learners.	1	Robotics activities enable and moti□vate young learners to learn and apply Algorithmic Think□ing through tangible robots, interactive tasks and immediate feedback, echoing previous research fndings on the environments to develop Algorithmic Thinking skill in young learners	Improvement of Students' Ability
Peribañez, E., Bayona, S., San Martin, J., Verde, A., Garre, C., Leoste, J., & Pastor, L. (2023). An Experimental Methodology for Introducing Educational Robotics and Storytelling in Therapeutical Activities for Children with Neurodevelopmental Disorders. Machines, 11(6), 629.	experimental methodology	some children	Children (Pre kindergarten)	children with NDD (neurodevelopmental disorders)		Results regarding the children's task involvement, level of attention, and use of social skills were positive. In addition, the attitude of some children changed throughout the sessions, improving frustration tolerance. The discussion of the pilot study provides clues for improving future implementations of the presented methodology, which serves as a framework for the design of future experiments that include therapeutic activities with educational robotics, gamification, and storytelling.	1	involved makes their widespread introduction difficult and leads to case-specific rather than more generalizable methods	Evaluation of Integrated STEM in Educational Robotics

Figure 2. Matrix Concept (Source: https://uns.id/MatrixConceptHusein)

Research Question 1: The Influence of Integrated STEM with Educational Robotics

This division can be further divided into three subgroups: the first focuses on improving students' abilities, the effectiveness of the teaching-learning process, and its connection to enhancing 21st-century skills. These subcategories are crucial benchmarks for evaluating the effect of combining STEM Education with Educational Robotics on the comprehensive enhancement of students' competencies and skill set. Evaluating the growth in students' adaptability, critical thinking, and collaborative aptitude within the integrated STEM setting becomes essential within this framework.

Another important subgroup involves examining the effectiveness of the teaching-learning processes within the integrated STEM and Educational Robotics paradigm. It investigates the efficiency of instructional approaches, the utilization of technology, and the significance of educators in establishing an optimal learning atmosphere. This assessment reveals how the combination of integrated STEM with Educational Robotics influences instructional approaches and promotes a more engaging and interactive learning environment.

Moreover, the correlation between integrated STEM and the reinforcement of 21st-century skills is a significant subcategory. It explores the influence of combining these educational methods on fostering crucial skills needed in today's society, including adaptability, creativity, problem-solving, and collaboration.. This examination emphasizes the interconnection between integrated STEM education and the cultivation of skills necessary for students to succeed in navigating the complexities of the contemporary world.

Improvement of Students' Ability

Robotics education in integrated STEM has a significant impact on students' ability to understand existing technological advances. For example, Engaging in robotics activities encourages and inspires young learners to grasp and utilize Algorithmic Thinking via hands-on robots, interactive exercises, and instant feedback. This mirrors earlier research conclusions regarding the settings that foster the development of Algorithmic Thinking abilities in children (Ching & Hsu, 2023). Educational robotics evidently provides results on the effectiveness of instruction by improving students' coding skills Diago et al. (2022). By employing Bee-bot robotics, the study revealed that the approach through Educational robotics had greater success than the traditional learning approach.

As a promising skill in the 21st century, One approach to achieving computational thinking involves expanding upon a remote robot programming task using four different experimental conditions. (Chevalier et al., 2022). As it appears, the amalgamation of STEM education with educational robotics elevates students' enthusiasm toward coding, computer science, and engineering. In a study (Negrini & Giang, 2019) Studying how students view educational robotics in formal education as a means to boost creativity, collaboration, and computer science skills, and to ignite their enthusiasm for STEM subjects. (Montuori et al., 2023) Demonstrates that Educational Robotics contributes to enhancing children's abilities, leading to broader cognitive improvements, particularly in areas like visuo-spatial skills.

It's clear that Educational Robotics extends beyond proficiency in resolving coding issues based on computers (near transfer effect) And through coding instructions, Educational Robotics statistically contributes significantly to children's collaborative problem-solving abilities (Yeung et al., 2024) compared to traditional paper and pen media (Çakır et al., 2021). Furthermore, in this study, the children were divided into experimental groups which shows that educational robotics also affects collaboration and cooperation skills.

The Impact on Teaching and Learning Process

Incorporating educational robotics into STEM education presents various benefits, especially in strengthening the methods of teaching and learning. (Christopoulos et al., 2022) research illustrates the feasibility of employing a blended learning approach in robotics education. This proves effective not just in imparting knowledge about robotics but also in cultivating 21st-century competencies among students, enabling them to recognize future challenges proficiently. Moreover, this study establishes that the Blended Learning model, coupled with educational robotics lessons, significantly enhances technological understanding, thereby enriching the overall learning experience. Expanding on this, (Lavi et al., 2021) expound on STEM learning skills, demonstrating their close relationship with active learning methods.

Other abilities relate to broader areas, encompassing complex problem-solving, critical thinking, self-directed learning, and formulating inquiries. Additionally, when dealing with Education 4.0 by merging mobile devices with educational robotics, it was demonstrated that educational robotics simplifies the potential for integrating technology into the educational journey and this implied that Educational Robotic could be used to improve the learning approach (Tselegkaridis & Sapounidis, 2022). This is achieved through kits containing sensors, mechanisms, components, and attributes that can be united and merged with mobile phones to construct operational robots (Restrepo-Echeverri et al., 2022).

To enhance the comprehension of programming concepts within the teaching and learning process among pre-service educators, integrated STEM-based robotics education proves notably effective in significantly refining these skills.. As the study Fegely and Tang (2022) has explained. Trained pre-service teachers will be better at conducting teaching and learning processes by understanding programming concepts through integrated Educational robotics..

Facilitate 21st Century Skills

(Gratani & Giannandrea, 2022) portray Educational Robotics in their research as a potent instrument, not solely for acquiring programming knowledge, but also for enhancing versatile abilities like problem-solving, metacognition, innovative thinking, creativity, and teamwork.. Moreover, the cultivation of computational thinking serves as a gateway to foster 21st-century skill sets (Amri et al., 2022). This is related to research by Bano et al. (2023) which shows that Educational Robotic helps in the proper and flexible understanding of integrated STEM concepts to support 21st century skills.Last, research De la Hoz et al. (2023) also shows that Educational Robotic is used as learning that promotes healthy hydration habits and the effectiveness of biosanitation knowledge in young populations. This indicates that Educational Robotics not only facilitates the acquisition of technological knowledge but also fosters the development of technology, a fundamental component of 21st-century skills.

Research Question 2: Evaluation of STEM Integrated with Educational Robotics on 21st Century Skills

In the second part, the focus will be on the Evaluation of Integrated STEM with Educational Robotics on 21st-century skills, referring to the implementation of conducted research. There are two stages that will be discussed. The initial phase underscores the significance of Educational Robotics in fostering 21st-century skills, while the subsequent phase involves assessing the integration of STEM within Educational Robotics following the implementation of research.

The importance of Educational Robotics in supporting 21st Century Skills

According to (Puškar et al., 2023), Educational Robotics represents a platform fostering interdisciplinary education, enabling students to explore the interplay and mutual enhancement of diverse academic domains. This facilitates customized learning experiences aimed at involving students in honing their problem-solving, critical thinking, collaborative at teams (Norris et al., 2023), and practical skills-key components of 21st-century competencies. Educational robotics has become a place in policies around the world (Mukhasheva et al., 2023). This research demonstrated that the impact of Educational robotics on the cognitive abilities of students meeting specific criteria yielded a notably higher effect size in comparison to learning methods not involving robotics, as evidenced by the meta-analysis. This suggests that Educational robotics is critical in its implementation to support 21st century skills and through Educational Robotics (ER), educators and students can enhance their creative skills and gain inspiration (Ramos-Teodoro et al., 2022) .

Evaluation of Integrated STEM in Educational Robotics

When applied, Educational Robotics significantly reinforces 21st-century skills via the application of computational thinking. However, the limitations of physically expensive educational robotics have limited its widespread use in the classroom. There should to be additional options for instructing students in educational robotics, like employing virtual educational robots (AR Bot) that provide 3D visual learning feedback. The application of robots to real-life cases can be an alternative to support children's debugging process in understanding new things (Misirli & Komis, 2023). This approach aims to enhance spatial abilities, crucial in reinforcing computational thinking, seen as a facilitator for 21st-century skill development (Yang et al., 2023). Educational robotics contributes significantly to therapy for children diagnosed with neurodevelopmental disorders (NDD), particularly when integrated into activities and narrative-based sessions (Peribañez et al., 2023). The results provided by the methodology were positive and were able to provide a different impression between before and after the methodology was implemented. Equivalent to that, there should be comprehensive STEM learning, systematic workflow steps, and various adjustments with careful consideration to achieve an inclusive STEM education (Bardoe et al., 2023).

In supporting the interests and talents of children, Educational Robotics also affects emotional responses if applied in other ways such as educational games. As in research Lei and Rau (2023) shows that Utilizing memory games designed with humanoid robots as interactive partners encourages collaboration and competition between humans and robots. This interactive approach underscores the positive influence of robotics on enhancing children's cognitive abilities and fostering creativity (Rapti & Sapounidis, 2024). Educational Robotics serves as a mechanism enabling students to enhance their cognitive abilities (Socratous & Ioannou, 2022). Through this, the research focused on the Educational robotics curriculum implemented in a structured and unstructured manner. The result was that the structured curriculum helped students achieve higher levels of metacognition and better collaboration. Furthermore, teachers' mastery of the STEM approach would have a greater impact when coupled with computational thinking for more effective learning (Çiftçi & Topçu, 2023) and this would make it easier to indicate that STEM teachers experience an enhancement in self-efficacy, computational thinking, and entrepreneurship skills (Şahin et al., 2024). Through this, there is a need for learning experiences that involve not only students but also teacher-peer interactions and performance products from teachers that align with the learning objectives (Huang et al., 2022).

Conclusion

Exploring the fusion of STEM Education and Educational Robotics between 2019 to 2023 provided encouraging observations regarding the advancement of 21st-century skills. Through a systematic analysis, it became evident that the implementation of integrated STEM significantly enhanced students' adaptability, creativity, critical thinking, and collaborative abilities within STEM-oriented tasks (Negrini & Giang, 2019). These findings emphasize the potential for a deeper fusion of integrated STEM education and Educational Robotics within educational frameworks.

Furthermore, the review highlighted the crucial role of merging STEM Education with Educational Robotics in creating dynamic and immersive learning environments (Puškar et al., 2023). The integration of robotics technology generated excitement among students for STEM fields, fostering creativity and encouraging active involvement in the educational journey (Lavi et al., 2021). This underscores the ongoing need for innovation and the utilization of cutting-edge technology to enhance students' educational experiences within the integrated STEM domain. However, the review also identified challenges (Christopoulos et al., 2022), including the need for a structured curriculum (Socratous & Ioannou, 2022), sufficient technological resources (Peribañez et al., 2023), and comprehensive educator training (Fegely & Tang, 2022) to seamlessly integrate this innovative integrated STEM approach into teaching methodologies. Overcoming these obstacles requires continuous investment and collaborative efforts across various sectors.

In Conclusion, Integrated STEM Education and Educational Robotics offers a hopeful avenue to nurture crucial 21st-century competencies in students.. Addressing the existing challenges is vital to ensure the effective implementation of integrated STEM methodologies. With sustained dedication and ongoing investment, this integration can serve as a strong foundation for preparing the next generation for the complexities of the future.

Notes

This link provides access to the comprehensive matrix concept: https://uns.id/MatrixConceptHusein

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