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# AI Technologies in STEAM Education for Students: Systematic Literature Review

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**Abstract**

*This study aimed to identify trends in the research conducted on Artificial Intelligence (AI) in STEAM (Science, Technology, Engineering, Arts, and Mathematics) education. To achieve this goal, a total of 16 articles were reviewed from the Web of Science (WOS) database. The analysis revealed an increase in the number of educational AI studies in 2021 and 2022, with Spain and South Korea emerging as the leading countries in implementing AI technologies in STEAM (Science, Technology, Engineering, Arts, and Mathematics) education. Quantitative research methods were predominantly employed in the reviewed articles, and most of the studies focused on primary and secondary students as the target sample. Among the various AI applications, educational robots were found to be the most commonly utilized in STEAM education. The findings of the study demonstrated that AI technologies contribute to the development of thinking skills, such as computational and analytical thinking, enhance self-confidence, increase satisfaction and enjoyment among students, and also deepen their understanding of STEAM concepts. These insights have important implications for teachers, practitioners, and policymakers in making informed decisions regarding the effective integration of AI in STEAM education. Furthermore, the results obtained in this study are expected to guide future research in this field.*

**Keywords:** *Artificial Intelligence, Students, STEAM Education, Systematic Literature Review.*

## Introduction

Artificial Intelligence (AI) has revolutionized all sectors of life, and education is no exception. As the world prioritizes learning in Science, Technology, Engineering, Arts, and Mathematics (STEAM) to meet the demands of an evolving labor market, integration with cutting-edge technology has become crucial to enhance students' learning outcomes (Xie et al., 2019). The STEAM fields are increasingly recognized as essential for developing 21st-century skills, prompting educators to explore innovative approaches to teaching and learning (Henriksen et al., 2017). In this context, various AI technologies have emerged as powerful scaffolds for learners, enabling more effective study methods and comprehensive assistance for teachers (Holmes et al., 2019). These technologies span a wide range, including natural language processing, immersive technologies, chatbots, and robotics (Luckin et al., 2016). More recently, large language models such as ChatGPT, Gemini, GitHub Copilot, and Claude have begun to make significant impacts in educational settings (Bender et al., 2021). Natural language processing (NLP) has facilitated more intuitive interactions between students and educational content, enabling personalized learning experiences and automated feedback systems (Luan et al., 2020). Immersive technologies, such as virtual and augmented reality, have transformed abstract STEAM concepts into tangible, interactive experiences, enhancing student engagement and understanding (Radianti et al., 2020). Chatbots and AI-driven tutoring systems have provided students with 24/7 access to learning support, offering personalized guidance and answering queries in real-time (Winkler & Söllner, 2018). In the realm of robotics, AI-powered educational robots have been instrumental in teaching coding, engineering principles, and problem-solving skills in a hands-on manner (Anwar et al., 2019). We feel that synthesizing the literature of AI use in STEAM context is critically needed due to the rapid advancement and proliferation of AI technologies in educational settings (Holmes et al., 2019; Zawacki-Richter et al., 2019). The surge in research studies, pilot programs, and implementations across various STEAM disciplines has led to a wealth of information that is often fragmented and dispersed (Xie et al., 2019; Luckin et al., 2016). A comprehensive review would offer a holistic view of the landscape, identifying overarching trends, common challenges, and best practices that

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emerge across different STEAM subjects and educational levels (Hew et al., 2019; Radianti et al., 2020). This synthesis is crucial for informing evidence-based decision-making in curriculum design, educational policy, and technology integration (Tuomi, 2018; Bocconi et al., 2020). Moreover, it would bridge the gap between theoretical research and practical implementation, providing educators with a clear roadmap for effectively incorporating AI tools into their STEAM teaching practices (Touretzky et al., 2019; Chai et al., 2018).

The significance of such a systematic review for the body of knowledge is substantial. It would consolidate the current understanding of AI's role in STEAM education, identify research gaps, and offer critical analysis of methodologies used in AI-STEAM integration studies (Zawacki-Richter et al., 2019; Goksel & Bozkurt, 2019). This comprehensive overview would assess AI's impact on student engagement, learning outcomes, and skill development across STEAM disciplines (Kulik & Fletcher, 2016; Baker, 2019), while also exploring ethical implications and potential biases (Zimmerman, 2018; Floridi et al., 2018). By facilitating cross-disciplinary insights and informing policy-making and funding decisions, the review would support the development of responsible AI integration practices and help prepare the next generation of STEAM educators (Corbett & Spinello, 2020; Long & Magerko, 2020). Ultimately, this systematic review would serve as a cornerstone in the evolving landscape of educational technology, paving the way for more informed, effective, and ethical integration of AI in STEAM education, and contributing to the advancement of both educational practices and AI technologies tailored for learning environments (How & Hung, 2019; Gadanidis, 2017).

## Literature Review

Over the past decade, there has been a significant rise in the application of artificial intelligence (AI) methods across various academic disciplines, driven by advancements in data processing and computing technologies. One interdisciplinary field that has emerged is Artificial Intelligence in Education (AI), which utilizes AI methods to enhance instruction, learning, and decision-making processes. The integration of AIEd into educational settings holds great promise for transforming traditional approaches to education and revolutionizing teaching and learning methods (Hwang, Xie, Wah, & Gašević, 2020). AI has been a subject of academic research for more than three decades, combining the power of AI with the learning sciences to advance the development of adaptive learning environments and other effective AIEd tools (Luckin, Holmes, Griffiths, & Forcier, 2016) Recent advancements in AI have enabled the exploration of various AIEd models, fulfilling the potential to revolutionize education through the creation of personalized and adaptive learning systems.

Furthermore, AI has significant implications for education. The integration of AI technologies in education can provide students with enhanced learning opportunities and improved outcomes. Studies demonstrate how AI can be leveraged to enhance education by facilitating personalized learning experiences, supporting problem-solving and critical thinking skills, and fostering creativity and innovation (OECD, 2018; UNESCO, 2018).

The emergence and ongoing development of AI have provided extensive opportunities for innovation in STEAM (science, technology, engineering, art, and mathematics) education. STEAM education focuses on integrating STEM subjects to enhance students' interdisciplinary knowledge, understanding, higher-order thinking, and problem-solving skill (Karampelas, 2020). The rise of STEAM can be traced back to 2008 when the Rhode Island School of Design (RISD) launched a low-to-no-cost initiative aimed at fostering creativity (Allina, 2018). This initiative sought to integrate arts and design education with STEM disciplines, driven by the overarching objective of sustaining America's position as an innovator (Maeda, 2012).

### *Relevant Work*

A substantial body of research synthesis exists in the realm of AI in education (e.g., Chen et al., 2020; García-Martínez, 2023; Rodríguez-Hernández et al., 2021). However, little is known about how research has been conducted in the specific context of AI and STEM education. There is a scarcity of studies employing systematic review analyses on the use of AI in enhancing students' academic achievement.

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Nagaraj et al. (2023) examined 50 records with the aim of inquiring into the effect of AI on STEM education regarding methodologies of teaching and learning, design of curriculum, engagement of students, practices of appraisal, strategies of institutions. Their results indicate that the integration of AI in STEM higher education shows promise in enhancing personalized learning experiences, improving student engagement, and providing more efficient assessment and feedback systems. Another significant effort was undertaken by Xu and Ouyang (2022), who reviewed 63 peer-reviewed articles examining AI in STEM education from 2011 to 2022. Their findings suggest that AI enhanced STEM education, particularly in higher education contexts. Technology and Science were the most prominently researched subjects using AI (24% and 22%, respectively). The studies employed diverse methodological approaches and sampling systems, with medium-scale samples being the most common. Among the six categories that emerged from the selected studies, the computer system category was predominant. Additionally, Ouyang and Xu's (2024) study provide a comprehensive meta-analysis on the impact of educational robotics in K-16 STEM education, synthesizing findings from 21 studies conducted between 2010 and 2022. The research examines how educational robotics influence learning outcomes, including performance, attitudes, and computational thinking skills. The results indicate that educational robotics have a moderate positive effect on students' learning performance and attitudes toward STEM subjects, but the impact on developing computational thinking skills is insignificant. This suggests that while robotics can engage and motivate students, their effectiveness in enhancing specific cognitive skills may be limited. The study also explores the role of moderating factors such as discipline, educational level, and instructional strategies, revealing that the effectiveness of robotics varies significantly across different STEM disciplines.

*Research Gap and Aim*

While AI has become a significant component in today's educational landscape, there appears to be a lack of comprehensive reviews specifically focused on the application of AI technologies in STEAM (Science, Technology, Engineering, Arts, and Mathematics) education. The existing gaps in the literature highlight the need for a consolidated and analytical collection of current studies on the use of AI in STEAM education. While there have been studies that address the systematic review of artificial intelligence in STEM, there is a dearth of research specifically examining STEAM. A systematic mapping review was conducted by (Conde et al., 2020) (Mejias et al., 2021) to investigate previous research regarding the use of robotics and mechatronics in STEM education. The results of their studies revealed that using robotics and physical devices gives hope in engaging students and assist acquiring skills of 21st century in STEM education conducted a review exploring the benefits and challenges of AI and new technologies in inclusive education for minority students. The review highlights advantages such as improved student performance and increased interest in STEM/STEAM subjects. Therefore, conducting a systematic review would be timely to uncover the trends and research context within this domain (Petticrew & Roberts, 2008).

In this context, the present research seeks to conduct a systematic investigation into the effects of AI technologies on STEAM education, focusing specifically on studies pertaining to students. The analysis will be conducted using the SSCI and SCIE databases within the Web of Science. With these objectives in mind, the study aims to address the following research questions:

What are the trends of AI technologies in STEAM education?

What types of AI technologies are used in STEAM education?

What are the benefits of applying AI technologies in STEM education on students?

*Materials and Methods*

To get to a high-quality level of articles regardless any conventions or approaches, the study included database of related publications in the WOS (web of science). In the scan conducted on January 2024, the search string was TITLE-ABS-KEY ("artificial intelligence" OR "AI" OR "AIED" OR "machine learning" OR "learning analytics" OR "intelligent tutoring system" OR "robotics" OR “expert system” OR "feedback system” OR “personalized learning” OR “adaptive learning” OR "ChatGPT" OR "algorithm" OR

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"computer vision" OR virtual agent" OR "automated assessment" OR " OR "deep learning" OR "reinforcement learning" OR "neural networks" OR "knowledge representation" OR "cognitive computing") AND ("STEAM") AND ("student" OR "learning" OR "teaching" OR "Curriculum" course" OR "class"). The PRISMA guidelines were adopted as the methodological approach for this systematic review, as they provide a scientific and systematic framework suitable for this type of study. The open and detailed reporting of the review process ensures the overall quality of the research, as it allows readers to thoroughly evaluate the implementation of the research methodology.

*The Screening Processes*

Following the criteria showed in Table1, a manual screening was conducted to ensure relative importance of investigated publications in order to exclude any other irrelevant ones.

Finally, the total number of articles used in this review was (757). Furthermore, the inclusion and exclusion criteria used in this study are shown in Table 1. The analytic research framework is illustrated in Figure 1.

Records identified from*:
Databases (n =757) WOS

Records removed *before screening*:
Duplicate records removed
(n=0)

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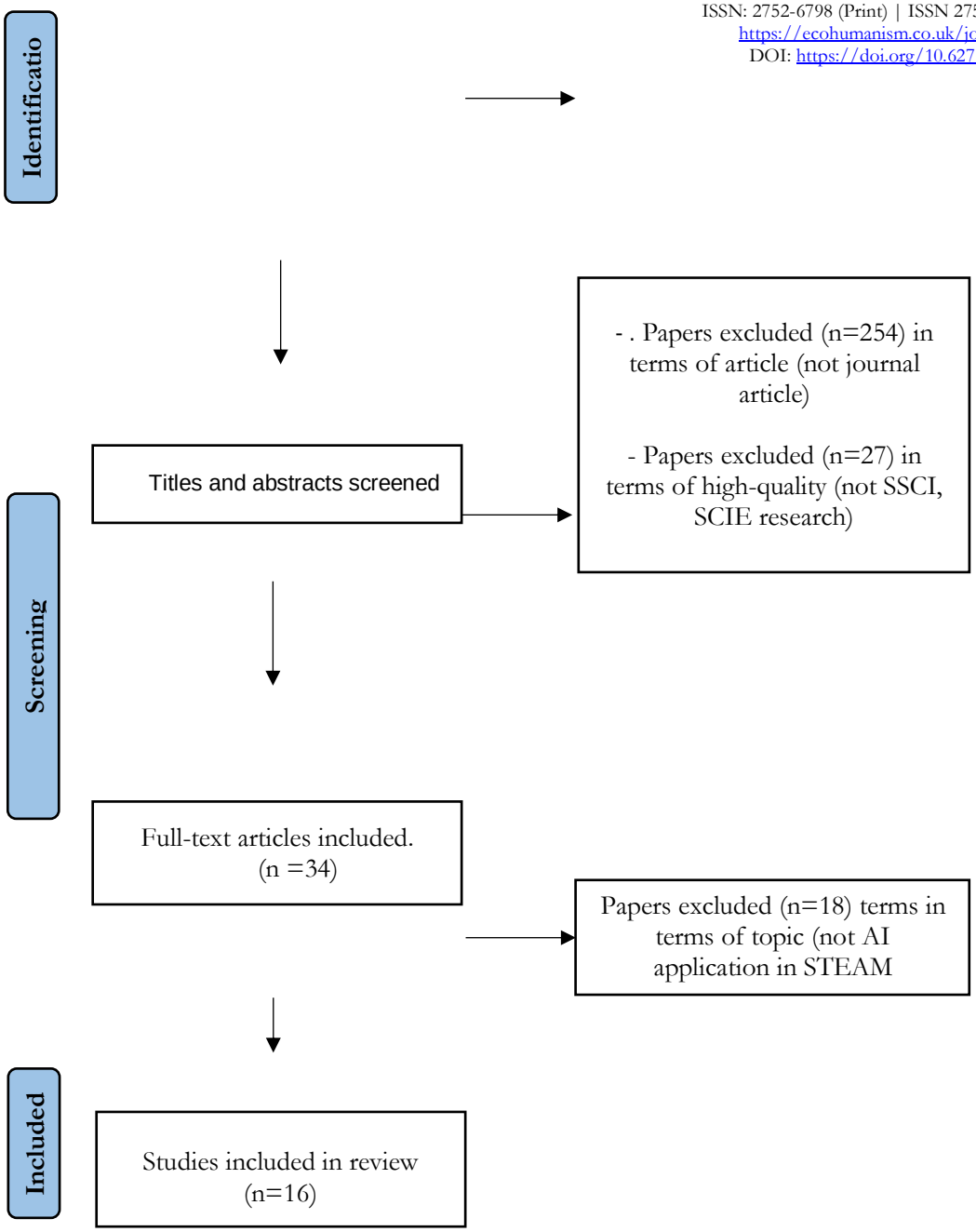


**Fig. 1. Analytic Framework of The Stud**

*Include and Exclude Criteria*

Several criteria were identified for selecting the articles to be included in this review. The primary objective of this study is to conduct a comprehensive analysis of the latest literature in order to understand the current trends and directions in the application of AI technologies within STEAM education. Accordingly, the publication period considered for inclusion in this review spanned from 2008 to 2023 (refer to Table 1). Only English articles were included in the review process, resulting in a total of 757 studies initially identified. High-quality articles meeting the criteria were included, while other types such as conference papers, working papers, and review articles were excluded. The focus was specifically on topics related to the application of Artificial Intelligence in STEAM education, with an emphasis on the benefits and effects of AI applications on students.

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To ensure the reliability and consistency of the study, the inter-rater agreement was calculated to be 95% (Miles, & Huberman 1994). This ratio shows an acceptable level of reliability. As a result of this rigorous evaluation, a total of 16 articles were identified that fully satisfied the criteria and were included in the systematic review.

**Table 1. The Inclusion and Exclusion Criteria**

| | |
|---|---|
| **Inclusion criteria** | The studies should be in the field of STEAM education with the support of artificial intelligence.<br>Articles published in reputed international journals (indexed) by WOS.<br>Articles in English<br>Year of publication between 2008 and 2023<br>Articles related to students |
| **Exclusion criteria** | Studies that are not education and educational research.<br>Studies that are not relevant to the research questions.<br>Articles unrelated to students such as teachers, curriculum, content, and others. |

*Data Abstraction and Analysis*

Selected papers were highly evaluated and explored, especially articles related to the study topics. Abstracts were carefully read; accordingly, data and analysis of the entire articles were collected. To ensure the reliability of the current work, a thematic analysis method was employed to analyze the data. The themes were defined and categorized by two independent authors, who grouped the findings based on their similarity or relevance. Additionally, the articles were analyzed based on the research questions to extract the main themes of the research.

A thorough discussion of the findings in Table is described in the Result section. The study examined the Years, Country, Types of AI, and Benefits of AI in STEAM education to address the research questions stated in the previous section.

**Table 2: A Narrative Summary to Guide the Reader Through Studies Based on Research Questions.**

| Author(s) / Year | Article Title | Country | methodology | Education Level | Types of AI | Benefits of applying AI Technologies |
|---|---|---|---|---|---|---|
| How, ML; Hung, WLD (2019) | Educing AI-Thinking in Science, Technology, Engineering, Arts, and Mathematics (STEAM) Education | Singapore | Qualitative | secondary | Bayesian data analytical techniques | developing skills such as computational thinking, analytical thinking, innovation, and prediction. Enhancing Students' Knowledge and Competencies through |

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| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | Deep Understanding of .Topics |
| Vicente, FR; Llinares, AZ; Sánchez, NM(2021) | Curriculum analysis and design, implementation, and validation of a STEAM project through educational robotics in primary education | Spain | Qualitative | primary | educational robotics kit | - Improved knowledge and deep understanding of sustainability among students. - Development of essential skills, including problem-solving, teamwork, critical thinking, and collaboration. |
| Wu, CH; Liu, CH; Huang, YM(2022) | The exploration of continuous learning intention in STEAM education through attitude, motivation, and cognitive load | Taiwan | Quantitative | Primary University | micro: bit | - The integration of Bloom's cognitive taxonomy, attitude, and motivation has led to a deeper understanding and learning .intention |
| Huang, XD; Qiao, CC(2022) | Enhancing Computational Thinking Skills Through Artificial Intelligence Education at a STEAM High School | China | Quantitative | secondary | AI | - enhances computational thinking. - boosts motivation and interest in learning and increases self-confidence. |
| Fernandes, NMMC; Zanon, DAV(2022) | Integration between educational robotics and the STEAM | Brazil | Qualitative | secondary | educational robotics (ER) | - Enhancement of active learning and student engagement |

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| | | | | | | |
|---|---|---|---|---|---|---|
| | approach: development of prototypes on the topic of social responsibility and sustainability | | | | | Development of multiple skills such as innovation, decision-making, problem-solving, communication, and collaboration. |
| Sullivan, A; Bers, MU(2018) | Dancing robots: integrating art, music, and robotics in Singapore's early childhood centers | USA | Quantitative | childhood | KIBO robotics | Mastery of foundational programming concepts Promotion of a collaborative and creative environment |
| Koerei, A; Szilagyi, S; Vaiciulyte, I(2023) | Task design for teaching cardioid curve with dynamic geometry software and educational robotics in university practice. | Lithuania | Quantitative | University | LEGO robot model | facilitate the learning of the cardioid curve. |
| Ince, EY; Koc, M(2021) | The consequences of robotics programming education on computational thinking skills: An intervention of the Young Engineer's Workshop (YEW) | Turkey | Quantitative | middle and secondary | block-based programming | Development of computational thinking skills Increased satisfaction and enjoyment among students through their participation in activities |
| Juskeviciene, A; Stupuriene, G; | Computational thinking development through physical | Lithuania | Quantitative | primary | Educational materials within Arduino | Development of computational thinking abilities |

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| | | | | | | |
|---|---|---|---|---|---|---|
| Jevsikova, T(2021) | computing activities in STEAM education | | | | | Increased - ability to analyze problems, decompose them, communicate, and create algorithms. |
| Sung, JHY; Lee, JY; Chun, HY(2023( | Short-term effects of a classroom-based STEAM program using robotic kits on children in South Korea | South Korea | Quantitative | childhood | KIBO Robotic | increases - in computational thinking. increases in - expressive vocabulary. Improvin - g social skills and self-confidence. |
| Arís, N; Orcos, L(2019) | Educational Robotics in the Stage of Secondary Education: Empirical Study on Motivation and STEM Skills | Spain | Quantitative | secondary | LEGO robotics | Increases - scientific curiosity and social skills. |
| Yoon, MB; Baek, JE(2018) | Development and Application of the STEAM Education Program Based on the Soccer Robot for Elementary Students | South Korea | Qualitative | primary | Soccer Robot | Expertise - and actuality of physical world. Self- - reflective learning that is collective and social |
| González-González, CS(2019) | State of the Art in the Teaching of Computational Thinking and Programming in Childhood Education | Spain | Qualitative | childhood | educational programming environments | Children - can create and program basic robot projects. Develop - computational thinking and problem-solving skills |

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| | | | | | | |
|---|---|---|---|---|---|---|
| Hacioglu, Y; Suiçmez, E(2022) | STEAM education in preschool education: We design our school for our visually impaired friend | Turkey | Qualitative | childhood | Bee-Bot | Designing - paths for the visually impaired and enhancing students' abilities in engineering, technology, and art |
| Kim, JO; Kim, J(2018) | Development and Application of Art Based STEAM Education Program Using Educational Robot | South Korea | Quantitative | primary | educational robot | develop - student abilities to solve scientific problems and artistic sensibilities |
| Hamash, M; Mohamed, H(2021) | BASAER Team: The First Arabic Robot Team for Building the Capacities of Visually Impaired Students to Build and Program Robots | Malaysia | Quantitative | Intermediate | Robot Kit | Enabling - blind and visually impaired students to build and program educational robots. Enhancing - students' abilities in technology, engineering, and art fields. |

## Results

Three main topics were presented in this section to answer the research questions as follows: (1)Tendency to AI technologies in stem education.; (2) The types of AI technologies used in STEAM education; and (3) The benefits of applying Artificial Intelligence in STEAM education, specifically for students.

RQ1: What are the trends of AI technologies in STEAM education?

The trends in the utilization of AI in STEAM education can be categorized into four research indicators: educational levels, publication year, countries of implementation and research methodology.

Publication year: The analysis results of the articles covered in the research by year are shown in Figure 3

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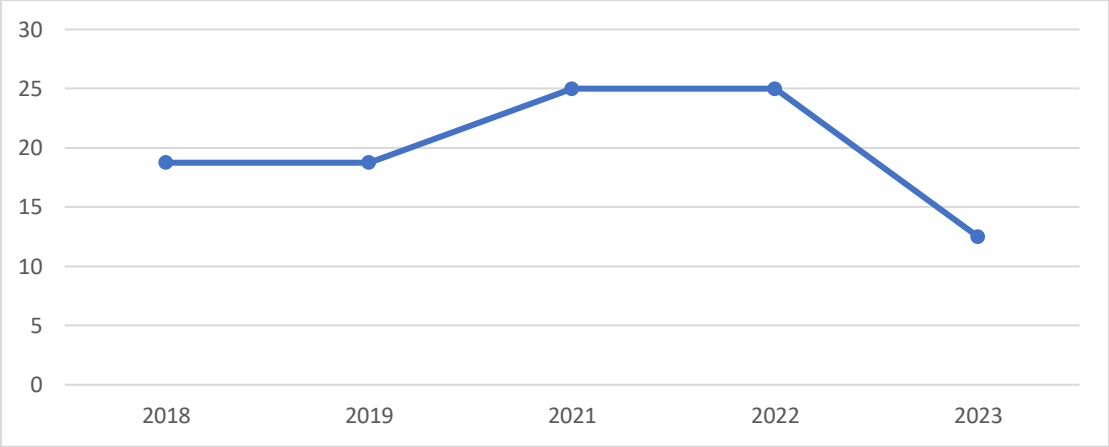


**Figure 2. Selected Papers Based on Years**

The analysis reveals that the study relied on SSCI and SCIE indexed articles, covering the period from 2008 to 2023. It is evident that there were no published studies related to the applications of AI in STEAM education before 2018. This may be due to the novelty of AI applications in this field. The majority of articles were published in 2021 and 2022 (with a total of 4 articles). Notably, there were three articles published in 2018 and 2019.

This overall trend indicates an increase in the number of articles over the years, with a slight decrease in 2023 compared to the previous year.

Countries of implementation: This review includes 16 studies based in ten countries. Chart 4 shows the selected studies distributed by country.

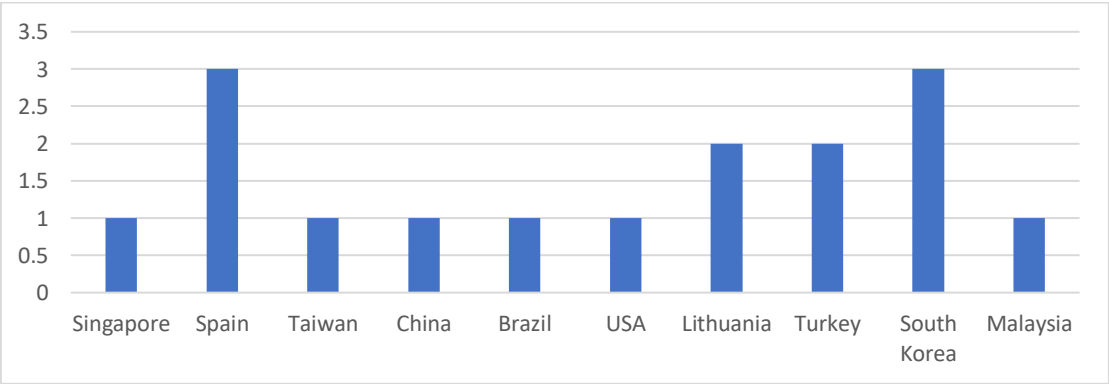


**Figure 3. Selected Papers Based on Country**

Most studies using AI technologies in STEM education were conducted by researchers in Spain and South Korea (n = 3). More than one publication was recorded in: Lithuania (n = 2) and Turkey (n = 2). Singapore, Taiwan, China, Brazil, USA, and Malaysia recorded only one.

Educational levels: Out of the 16 reviewed studies, the selected articles can be categorized into five educational levels. 28% of the studies focused on primary education, and another 28% focused on secondary education. The remaining studies were distributed among childhood (22%), intermediate (11%), and university (11%) education levels. It is important to note that a study can address multiple educational levels simultaneously.

Educational levels: Out of the 16 reviewed studies, the selected articles can be categorized into five educational levels. Twenty-eight percent (28%) of the reviewed studies focused on primary education, while

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another 28% focused on secondary education. The remaining studies were distributed among childhood (22%), intermediate (11%), and university (11%) education levels. It is important to note that a single study can address multiple educational levels simultaneously.

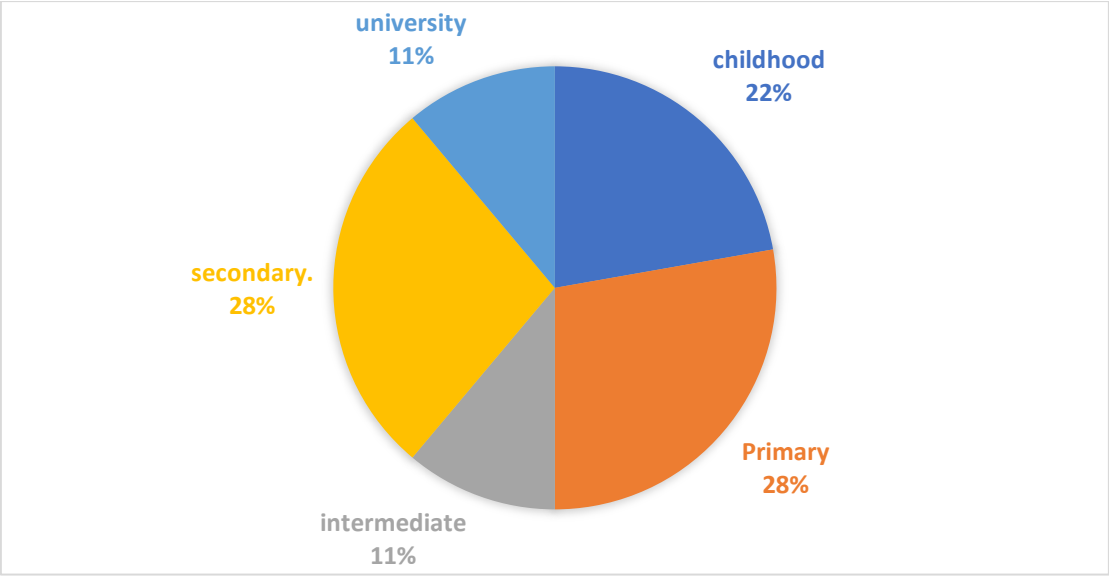


**Figure 4. Distribution Of Educational Levels Used in AI Studies In STEAM Education**

Research methodology: It was observed that quantitative methods were preferred in more than half (62%) of the studies (Figure 2). These were followed by qualitative methods (38%). One of the reasons why quantitative methods were often preferred may be related to the recent discovery of the potential of AI technologies in STEAM education. The large number of studies aiming to identify the effect of AI use on student learning also contributes to the prevalence of quantitative methods. Similarly, studies on educational technologies predominantly make use of quantitative methods.

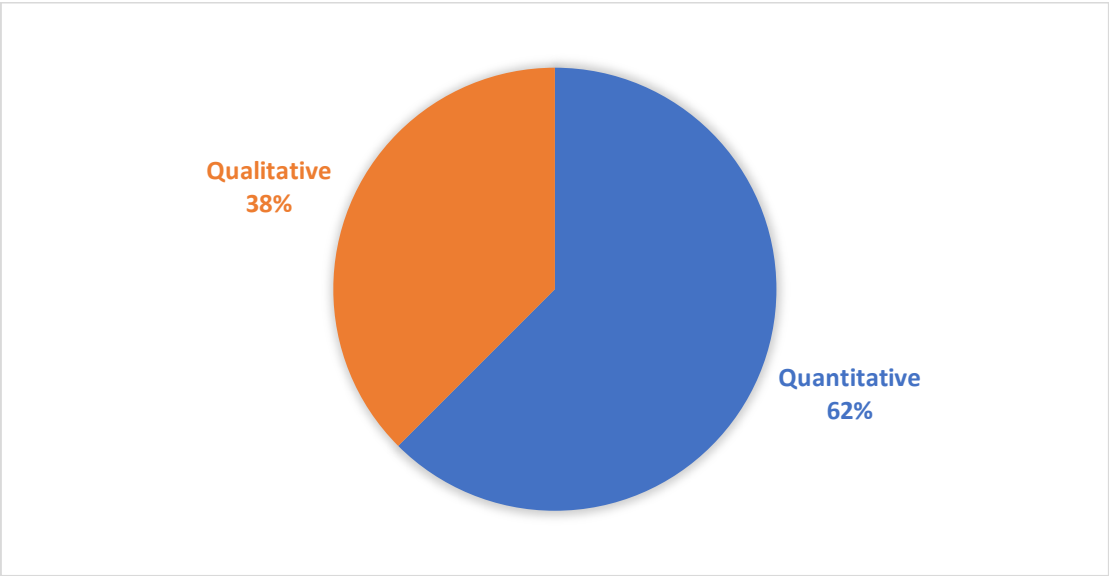


**Figure 5. Distribution of Methodology Used in AI Studies in STEAM Education**

RQ2: What types of AI technologies used in STEAM education?

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Five categories of AI technologies were utilized in STEAM education in the selected studies. Nine studies focused on Educational Robots, four studies employed Programming Systems, one study used Bayesian data analysis techniques, one study focused on educational materials within Arduino, and one study utilized Artificial Intelligence (AI). Table 4 provides a summary of the AI technologies employed in STEAM educational settings in the reviewed studies.

**Table 3. AI Technologies Used in STEAM Education.**

| AI and new technologies | N | Percentage |
|---|---|---|
| Educational Robot | 9 | 56% |
| Bayesian data analytical techniques | 1 | 6.25% |
| Programming System | 4 | 25% |
| Educational materials within Arduino | 1 | 6.25% |
| Artificial intelligence (AI) | 1 | 6.25% |

The results revealed that using robots is an outstanding category of AI and new technologies in STEM education.

In particular, educational robots are rapidly advancing technologies that play a crucial role in equipping students with essential skills and preparing them for the future. These robots come in various types, as evidenced in (Sullivan & Bers 2018), the study that utilized the KIBO robot to enhance young students' understanding of foundational programming concepts. Additionally, (Koerei et al. 2023), I's (2023) study focused on the LEGO robot to train students in drawing the cardioid curve. Furthermore, [16] conducted a study that utilized a variety of educational robots, including the VGo Robot Avatar, PIONEER, and TERECo. This study emphasized that educational robots in the field of STEAM assist students in acquiring social skills such as communication, collaboration, decision-making, problem-solving, and innovation.

In addition, programming systems such as bots, were identified through reviewed studies.

A bot is a program that executes predefined, repetitive, and mechanized tasks, mimicking human behavior and operating at a faster pace due to its mechanized nature. For instance, a study conducted by (Hacioglu & Suiçmez 2022) applied Bee-BOT to design pathways for visually impaired individuals. Meanwhile, the study by (Wu et al. 2022) utilized MicroBot to assist students in deepening their understanding of knowledge and motivating them towards learning.

Another new technology identified by the review was Bayesian data analytical techniques. This technology can be used for data analysis and inference of results using prior knowledge and providing a flexible framework. For instance, the review found a study that employed Bayesian data analytical techniques to develop skills such as computational thinking (How & Hung, 2019). Arduino technology also focuses on empowering learners to explore electronics, programming, and learning in an easy and enjoyable way, as demonstrated by a study conducted by (Juskeviciene et al., 2021). Computational making activities with Arduino technology helped motivate and promote students' cognition in the light of the design of CT abilities developments in STEM that accompanied with teaching materials.

RQ3: What are the effects of applying AI technologies in STEM education on students' learning outcomes?

The effects of applying AI technologies in STEAM education, specifically on students' learning outcomes, can be classified into six categories, as shown in Table 4. Six studies highlighted improvements in student thinking, five studies mentioned enhanced acquisition of skills for students, four studies pointed out increased programming knowledge among students, three studies highlighted the development of deep understanding in students, three studies emphasized increased student motivation, and three studies indicated other additional benefits (as mentioned in Table 6).

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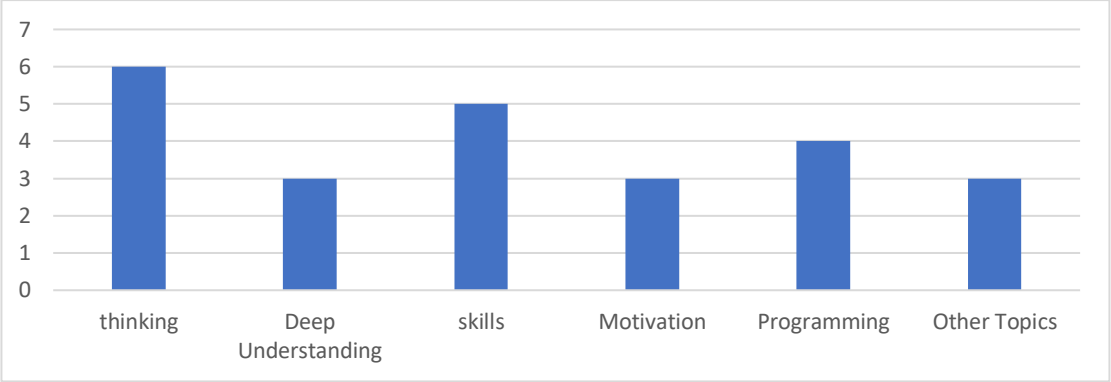


**Figure 6. Benefits of Using AI Technologies in STEAM Education for Students.**

From an educational perspective, several studies have reported the educational significance of applying AI techniques in STEAM education. Specifically, six studies indicate that the use of AI applications in STEAM enhances the ability to think in various ways, including critical and analytical thinking, especially computational thinking, across different educational stages. The studies conducted by (How & Hung, 2019) and (González, 2019) demonstrated significant development in computational thinking among all participants.

Additionally, three studies reported that AI and its applications contribute to deepening students' understanding and improving their comprehension skills (Vicente et al., 2021) and (Wu et al., 2022) found evidence supporting this claim.

Furthermore, five studies revealed that AI applications in STEAM education help students acquire and develop skills such as problem-solving, collaboration, communication, and decision-making. For example, (Kim, & Kim, 2018) conducted a quasi-experimental study that demonstrated the positive impact of an Art-Based STEAM Education Program using educational robots on students' problem-solving abilities in the experimental group compared to the control group.

Moreover, four studies highlighted that artificial intelligence applications assist students in acquiring basic programming concepts, algorithm design, and even creating and programming simple robotic projects. (Hamash, & Mohamed, 2021) specifically emphasized the empowering effect of artificial intelligence applications on visually impaired students in building and programming educational robots.

In terms of motivation and engagement, three studies showed that the use of artificial intelligence applications in STEAM education contributes to increased motivation and engagement among students, particularly among older participants, such as secondary school students. These applications also promote students' independence and self-confidence. For example, (Arís, & Orcos 2019) and (Fernandes & Zanon 2022) provided evidence supporting these findings.

Furthermore, AI applications in STEAM education have made contributions to various other areas. For instance, (Koerei, & Vaiciulyte 2023) demonstrated how these applications facilitate students' learning of the cardioid curve. (Sung, & Chun 2023) highlighted the role of artificial intelligence applications in increasing students' expressive abilities during childhood. Additionally, (Hacioglu & Suiçmez 2022) emphasized how these applications assist students in designing paths for visually impaired individuals.

## Discussion

The findings of this study provide a comprehensive overview of the trends in the application of artificial intelligence (AI) technologies within the context of STEAM education. A significant increase in scholarly attention to AI in STEAM education was noted post-2018, culminating in a peak of publications during 2021 and 2022. This trend aligns with the broader global movement towards integrating AI technologies

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into educational frameworks, reflecting a growing acknowledgment of their potential benefits, as noted by Nagaraj et al. (2023) and Xu and Ouyang (2022). The absence of studies prior to 2018 suggests that the application of AI in educational contexts was still in its infancy, with the technology evolving and establishing its pedagogical relevance. Geographically, the analysis reveals a concentration of research efforts in specific countries, notably Spain and South Korea, which may indicate regional leadership in the adoption and integration of AI technologies in education. This geographical distribution underscores the importance of understanding local contexts and policies that facilitate or hinder the implementation of AI in educational settings, as highlighted by the studies of Nagaraj et al. (2023) and Xu and Ouyang (2022). Furthermore, the balanced focus on both primary and secondary education highlights the significance of introducing AI tools early in the educational journey, emphasizing the interconnectedness of educational experiences across different levels.

Methodologically, the predominance of quantitative approaches in the reviewed studies is consistent with trends in educational technology research, as noted by Ouyang and Xu's (2024) meta-analysis on the impact of educational robotics in K-16 STEM education. The emphasis on quantitative methods may stem from the need to systematically measure the impact of AI applications on student learning outcomes. This approach aligns with broader educational research practices where quantifiable data is prioritized to demonstrate effectiveness and inform policy decisions. However, the integration of qualitative methodologies could provide a richer understanding of the nuanced experiences of students and educators interacting with AI technologies in STEAM contexts, as suggested by the current study.

The categorization of AI technologies utilized in STEAM education reveals that educational robots are the most frequently employed tools, as evidenced by the findings of Ouyang and Xu (2024). This trend reflects their potential to engage students and facilitate hands-on learning experiences. Additionally, the findings underscore the importance of programming systems and other AI technologies, such as Bayesian data analysis and Arduino, in enriching the educational landscape, aligning with the insights from Nagaraj et al. (2023) and Xu and Ouyang (2022).The impact of AI technologies on student learning outcomes is particularly noteworthy, with benefits categorized into six distinct areas, including improved thinking skills, enhanced acquisition of competencies, and increased motivation. These findings align with existing literature that emphasizes the positive influence of AI applications on critical and analytical thinking, as well as overall student engagement, as highlighted by the studies of Nagaraj et al. (2023) and Xu and Ouyang (2022).

Despite the valuable insights provided by this study, gaps in the existing literature remain evident. There is a scarcity of systematic reviews focused specifically on the intersection of AI and STEAM education, indicating an opportunity for future research to explore the long-term effects of AI integration on educational practices and student outcomes comprehensively. Notably, emerging studies are beginning to address this need, emphasizing the promise of AI in enhancing personalized learning experiences.

## Conclusion

This systematic review examined 16 studies on the use of AI technologies in STEAM education, with the aim of investigating the trends, types, and benefits of employing these technologies for students. The review demonstrates a consistent and growing interest in integrating AI technologies into STEAM education, with a particular focus on Spain and South Korea as the most active contributors in this area. The studies covered educational levels ranging from primary to secondary and adult education, with a notable peak in research dissemination in 2021 and 2022. Among the selected studies, the most commonly used AI technologies were Educational Robots and Programming Systems, reflecting their potential to engage students and facilitate hands-on learning experiences. Furthermore, this review identifies a range of benefits associated with the use of AI technologies in STEAM education. These include fostering critical thinking and analytical skills, enhancing students' deep understanding, boosting motivation and creativity, teaching fundamental programming concepts, enabling participation for disabled students, and facilitating diverse learning activities. The findings underscore the importance of understanding local contexts and policies that facilitate or hinder the implementation of AI in educational settings. Additionally, the review highlights

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the need for more qualitative research to provide a richer understanding of the nuanced experiences of students and educators interacting with AI technologies in STEAM contexts. Stakeholders, including teachers, should consider the implications of integrating AI technologies to support students in developing critical thinking, problem-solving, and creative abilities, as well as their understanding of AI.

### Limitations and Recommendations for Future Research

The findings presented in this systematic review are based on an analysis of 16 selected studies, which may limit the comprehensive understanding of this topic. Future research could address this limitation by searching additional databases (e.g., Scopus) or including a broader range of sources to expand the number of selected studies. Moreover, few studies have discussed the various types of AI technologies in STEAM education in detail. It is recommended that future empirical studies include other types of artificial intelligence applications that were not mentioned in the selected studies. Additionally, there is a lack of research focusing on intermediate school students. Therefore, further investigation is necessary to explore the application of artificial intelligence technologies in STEAM education for middle school students.

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