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A systematic review of the implementation of STEAM education in schools

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Abstract

This study aims to conduct a systematic review of the implementation of science, technology, engineering, art, and mathematics (STEAM) education in schools. Based on this aim, the study sought to identify the implementation of STEAM-based education and the impact of STEAM-based education using a systematic review approach. Fifteen articles were selected from the Scopus database based on inclusion and exclusion criteria. The data was analyzed using a systematic review approach. The results showed that all articles were published after 2019 and that these articles used different teaching methods to implement STEAM education. In addition, the results showed that implementing STEAM education focused on three dimensions. These are the effects of STEAM education on learning performance, affective factors, and development skills. The results show that implementing STEAM education in schools positively affected learners' learning achievement, affective factors, and development skills. Overall, STEAM education can help learners develop their learning outcomes. In light of our findings, we suggest implications for educational research on implementing STEAM education and further research.

Keywords: STEAM education, schools, systematic review, implementation, science education

INTRODUCTION

Science, technology, engineering, art, and mathematics (STEAM) education aims to teach innovation skills and creativity, essential for innovative thinking and innovation in the 21st century (Bertrand & Namukasa, 2020; Cheung, 2024). Art education aims to reveal people's creative abilities, so STEAM was born by integrating arts into STEM fields. As STEAM education programs are widely used in schools, it has become imperative to cultivate people who can look at problems critically, approach a problem from different angles, and focus on coming up with solutions, thinking creatively and innovatively (Bertrand & Namukasa, 2020; Hang et al., 2023; Syukri et al., 2022). Countries aiming to educate people with 21st century skills such as creative and innovative thinking have encouraged the spread of STEAM education at all levels of education. Adding art to STEM fields has created a foregone option for teaching (Tanabashi, 2021).

STEAM-based science education is expected to help increase learners' motivation at each educational level and enhance their interest in each discipline of the STEAM fields (Boytchev & Boytcheva, 2020; Chen & Dong, 2023; Ji, 2021). Many researchers have argued that student interest, achievement, and motivation can be increased in STEAM classes, especially in subjects that involve real-world problems, and that students are more likely to choose careers related to STEAM fields (Graván et al. (2020; Ifinedo Burt (2024; Ji, 2021) Researchers have reported positive findings about students' experiences in STEAM activities (Hung et al., 2024; Lin & Chiang, 2019). These studies concluded that STEAM activities had a moderately significant impact on student learning

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Contribution to the literature

- Although the importance of STEAM instruction for learners is well known, several studies have not conducted a systemic review focused on implementing STEAM instruction.
- In this research, we systematically examined empirical studies on STEAM-based education to clarify how researchers have introduced and implemented STEAM-based education to add new insights to the literature.
- The new findings from our results show that implementing STEAM education in schools positively impacts learners' learning achievement, affective factors, and developmental skills. Overall, STEAM education can help learners to improve their learning outcomes.

Table 1. Inclusion and exclusion criteria for systematic review

Inclusion criteria	Exclusion criteria
Studied conducted in schools	Not conducted in schools
It is educational research related to STEAM education	Non educational studies on the implementation of STEAM education.
It is empirical research with clear pedagogical goals of the implementation of STEAM education.	The article only mentions but does include results regarding the implementation of STEAM education.
Articles were published in English	Articles were published in other languages.

outcomes, such as attitudes and improved students' levels of scientific creativity (An, 2020; Breda et al., 2023; Ifinedo & Burt, 2024; Karppinen et al., 2017; Román-Graván et al., 2020). In addition, scholars pointed out that this interdisciplinary approach in STEAM education has the great potential to develop the esthetic dimensions of engineering and technology while meeting pressing societal needs through innovative educational practices (Dyer, 2019; El Bedewy et al., 2024). As Dyer (2019) suggested, STEAM education should go beyond aesthetics and focus on the fundamental principles of engineering solutions that meet societal needs.

In addition, previous studies have emphasized the importance of STEAM education in teaching important skills for future careers (Gu et al., 2023; Hung et al., 2024; Karppinen et al., 2017). In addition to enhancing subject-specific skills, STEAM education is critical for addressing broader educational challenges and gaining new perspectives on different disciplines (Karppinen et al., 2017). To paralleled the importance of STEAM education, several studies have addressed research trends (Kwan & Wong, 2021), bibliometrics (Supriyadi et al., 2023), meta-analyzes (Asrizal et al., 2023), and literature reviews (Kim et al., 2024; Pahmi et al., 2022) on STEAM education in the research literature. However, in reviewing previous studies that have addressed STEAM education and schools, no systemic reviews focused on schools in STEAM education. Namely, none of the existing reviews in the literature provided a systematic description of the implementation of STEAM-based education in schools from a pedagogical perspective. Therefore, we systematically examined empirical studies regarding STEAM-based education to clarify how researchers have introduced and implemented STEAM-based education. Furthermore, this lack of research addresses a research gap in the literature that necessitates the present study. Specifically, this study has three objectives:

(1) to identify the implementation of STEAM-based education and

(2) to identify the effects of STEAM-based education.

For this reason, this research is the first in literature and will be a source for future research.

METHOD

The method used for this research is a systematic review. Thus, this research method aimed to synthesize all the studies on implementing STEAM-based education in schools. Systematic reviews are often seen as the pinnacle because they provide precise and reliable scientific evidence. In this respect, systematic reviews are valuable for examining a study on a specific topic or issue.

Data Collection

This study's primary data source was research on STEAM implementation in schools. Data were collected from the Scopus databases in December 2024. The inclusion and exclusion criteria of the studies are listed in **Table 1**. Accordingly, we are involved in studies that meet our inclusion criteria because

(1) studies were conducted in schools,

(2) educational research related to STEAM education,

(3) empirical research with clear pedagogical aims and outcomes of implementing STEAM education, and

(4) the articles published in English.

In addition to these inclusion criteria, we did not use a period during the search in the database. Regarding the exclusion criteria, we did exclude studies that

Table 2. List of keywords

Main keywords	Alternatives of the main keywords	Search place
STEAM	STEAM; science, technology, engineering, arts, and mathematics; & STEAM education	Keywords
Implementation	Tutoring; mentoring; guidance; lessons; education; instruction; teaching; & training	Keywords

Table 3. A list of articles in the systematic review

Reference	Title	Source title
Hung et al. (2024)	Enhancing occupational therapy education: Evaluating the impact of a STEAM-based assistive technology curriculum using Kirkpatrick's four-level model	British Journal of Occupational Therapy
Kreis et al. (2024)	Transitioning from lectures to online flipped classrooms: enhancing pre-service teacher education in Luxembourg	Cogent Education
Infedo and Burt (2024)	Exploring the application of college student role models in service-learning pedagogy	Journal of Applied Research in Higher Education
Chen and Dong (2024)	Students' psychological analysis for classroom teaching strategies of art songs based on STEAM education	Sustainability
Gu et al. (2023)	Incorporating STEAM activities into creativity training in higher education	Thinking Skills and Creativity
Breda et al. (2023)	Utilising a STEAM-based approach to support calculus students' positive attitudes towards mathematics and enhance their learning outcomes	Open Education Studies
Haas et al. (2021)	Integrated STEAM approach in outdoor trails with elementary school pre-service teachers	Educational Technology and Society
Ji (2021)	Use of virtual reality technology in animation course teaching	International Journal of Emerging Technologies in Learning
Lu (2021)	Scratch teaching mode of a course for college students	International Journal of Emerging Technologies in Learning
An (2020)	The impact of STEAM integration on preservice teachers' disposition and knowledge	Journal of Research in Innovative Teaching & Learning
Boytchey and Boytcheva (2020)	Gamified evaluation in STEAM for higher education: A case study	Information
Román-Graván et al. (2020)	Perceptions about the use of educational robotics in the initial training of future teachers: A study on STEAM sustainability among female teachers	Sustainability
Kim et al. (2019)	Enabling creative collaboration for all levels of learning	PNAS
Karppinen et al. (2019)	Interdisciplinary craft designing and invention pedagogy in teacher education: Student teachers creating smart textiles	International Journal of Technology and Design Education
Lin and Chiang (2019)	Using 6E model in STEAM teaching activities to improve university students' learning satisfaction: A case of development seniors IoT smart cane creative design	Journal of Internet Technology

(1) were conducted with primary, middle, and secondary school students,

(2) are not pedagogical and did not provide empirical results on the implementation of STEAM education,

(3) did not include results on the implementation of STEAM education, and

(4) the articles published in the other languages except for English.

To collect data from the database, two researchers searched using keywords in the database. Table 2 shows a list of keywords used during the research. For STEAM and implementation keywords, researchers determined alternatives to the keywords and used them to search the articles published on the implementation of STEAM in schools. The search was conducted using keywords (see Table 2). During the initial search, the researcher found 136 documents in the database. Later, they limited the publication to journals and English options, so the number decreased to 40 documents. After this, they choose the article option to limit the documents. The result yielded 36 documents. Thus, two researchers read titles and abstracts of 36 articles for inclusion based on the inclusion and exclusion criteria. When they were not sure about the articles, they read the full text of the article.

Thus, in light of inclusion and exclusion criteria, the researcher determined the articles for systematic analysis in this research. Thus, the inclusion and exclusion analysis yielded 15 studies on STEAM implementation. The information about authors, titles, and journals of selected articles is given in Table 3. Thus, the systematic review included fifteen publications. This result means that researchers excluded 21 articles that did not meet the inclusion criteria.

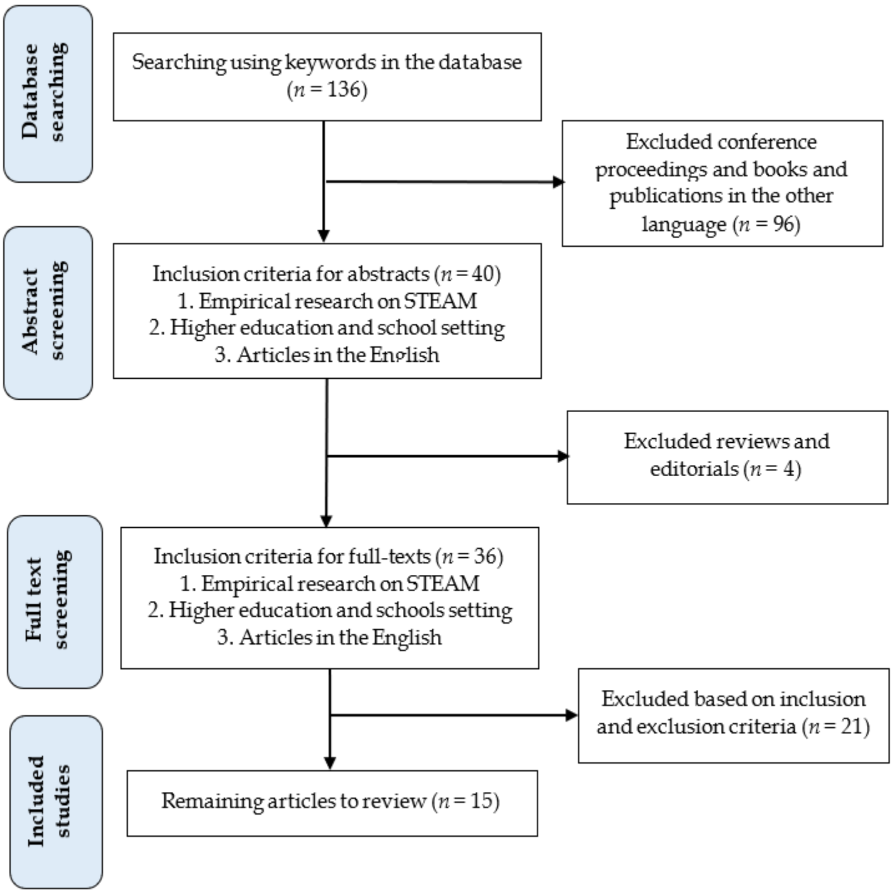

Figure 1. PRISMA flowchart of the systematic review (Source: Authors' own elaboration)

The PRISMA flowchart (Liberati et al., 2009) provides information on obtaining these studies (**Figure 1**).

Table 3 lists the 15 articles used for analysis.

Table 4 provides descriptive information about the aims of the 15 articles determined for analysis.

Table 4. The authors and aims of articles

Reference	Column 4
Hung et al. (2024)	The aim of this study was to describe the development of a STEAM-based assistive technology curriculum in occupational therapy and to evaluate its effectiveness.
Kreis et al. (2024)	Kreis (2024) evaluated the effectiveness of flipped classroom methods in STEAM education to identify the benefits and challenges associated with this pedagogical shift in teacher education.
Infedo and Burt (2024)	Ifinedo (2024) examined the impact of service learning with STEAM education on college students in Canada.
Chen and Dong (2024)	This study addresses evolving educational needs by focusing on students' psychological development and learning styles in the STEAM educational context.
Gu et al. (2023)	Gu (2023) wanted to develop a creativity course for college students that integrated STEAM activities (science, technology, engineering, art and math) to practice and strengthen the creative thinking skills needed in all fields.
Breda et al. (2023)	Breda (2023) investigated the effectiveness of a STEAM-based approach to improve students' attitudes towards mathematics and increase their learning outcomes in a calculus course at a college.
Haas et al. (2021)	The study investigated the impact of an integrated STEAM approach in the design of outdoor learning pathways by pre-service teachers during distance learning due to the COVID-19 pandemic.
Ji (2021)	This study examined the effectiveness of an animation lesson using the STEAM educational framework, focusing on student-centered learning. In addition, this study examined student satisfaction to assess expectations, perceived quality, perceived value, and loyalty to measure the effectiveness of the proposed instructional model.
Lu (2021)	This study investigated the impact of STEAM lessons with game-based learning on students' learning skills and innovative thinking.
An (2020)	This study investigated how the integration of STEAM into mathematics methods courses affects prospective teachers' attitudes, confidence and knowledge.

Table 4 (Continued). The authors and aims of articles

Reference	Column 4
Boytchey and Boytcheva (2020)	The study examined the effectiveness of STEAM education based on gamification evaluation in improving student engagement and learning outcomes of higher education students.
Román-Graván et al. (2020)	This study investigated how educational robotics can empower women and promote gender equality in teacher training.
Kim et al. (2019)	This study examined the effectiveness of STEAM education based on interdisciplinary research that combines psychology, art and transformative learning.
Karppinen et al. (2019)	This paper investigated the integration of interdisciplinary craft design and invention pedagogy into teacher education based on STEAM education to improve future educators' pedagogical skills and foster creativity and practical skills.
Lin and Chiang (2019)	N/A

Table 5. Coding features and their dimensions

Category	Dimension	Features
Instructors and instructional strategies	Instructor involvement	Researchers & not researchers
	Instructional strategy	Flipped classroom; lecture; PBL; problem-based learning; game-based learning; collaborative learning; & self-learning
Learners	Number of participants	Small scale (≤ 50); medium scale (51-300); & large scale (> 300)
Learning outcomes	Learning outcome	Learning performance; affective factors; & development skills
Environment	Educational context	Face-to-face instruction (i.e., classroom); experimental instruction (i.e., control and experimental group); informal learning environment (e.g., museum); remote teaching; & augmented/VR
Data collection	Data collection	Qualitative; quantitative; & mixed (quantitative + qualitative)

Table 6. A distribution of reviewed articles by years

Year	Number of articles	Percentage (%)
2024	4	27
2023	2	13
2021	3	20
2020	2	13
2019	4	27

Data Analysis

The first step for a systematic review was identifying the features relevant to STEAM education. To this end, we established five coding frameworks with four characteristics, namely

(1) instructors and instructional strategies,

(2) learners,

(3) focus content, and

(4) environment, to review the relevant studies on the implementation of STEAM education.

The information about our coding features and their dimensions and types can be found in **Table 5**. Two researchers analyzed the articles using coding dimensions and features during data analysis. Then, they compared their analysis. When they had disagreements about their coding and analyses, they discussed between themselves and agreed on a mutual decision. Thus, the researchers completed the coding step. Later, the researchers calculated the reliability score for the analysis and found a %93 agreement between researchers on the coding process.

RESULTS

Research Development Trend of STEAM Education

In this section, we analyze the development of relevant research on implementing STEAM education in schools by reviewing all publication dates. According to the publication date mentioned in 15 studies in **Table 6**, all articles were published after 2019. **Table 6** shows a distribution of reviewed articles by year. Most articles were published in 2019 and 2024 (N = 4). The year 2019 was critical because the implementation of STEAM education started this year. This result indicates a clear trend towards more research on STEAM education. The number of studies peaked in 2024. In 2020, two articles were published, and in 2021, there were three articles. In 2023, the number of articles was two.

Instructors and Instructional Methods

We examined the STEAM research implementation instructors and analyzed who delivered STEAM instruction in the studies examined. Accordingly, we found that all 15 studies we reviewed mentioned that the researchers were involved in implementing STEAM lessons in classrooms. This means that the researchers, the authors of all 15 articles, implemented STEAM instruction in their studies themselves. As for the teaching strategies used in STEAM education research, we found that action research, collaborative learning, design-based learning, flipped classroom, game-based learning, hands-on activities, inquiry-based learning, lecture, problem-based learning, project-based learning

Table 7. Results on instructional methods

Focus content	N
Action research study	1
Collaborative learning	6
Design-based	1
Flipped classroom	1
Game-based learning	1
Hands-on activities	1
Inquiry-based learning	1
Lecture	4
Problem-based learning	3
PBL	1
Outdoor education	1
Self-learning	2
Virtual teaching	1

Table 8. Results on learners

Participant sizes	Number of participants (N)
Small scale (≤ 50)	6
Medium scale (51-300)	6
Large scale (> 300)	2
NA	1

(PBL), outdoor learning, self-learning, and virtual learning were mentioned in all studies (see **Table 7**). In 15 articles, the lecturer most frequently used the collaborative learning strategy (N = 6), followed by the traditional teaching method through lectures (N = 4). In addition, some studies were conducted through problem-based learning (N = 3), self-learning (N = 2), game-based learning (N = 1), action research (N = 1), design-based (N = 1), flipped classroom (N = 1), hands-on activities (N = 1), inquiry-based learning (N = 1), PBL (N = 1), outdoor instruction (N = 1), and virtual instruction.

Learners of STEAM Research

Of the 15 studies examined, five studies involved pre-service teachers as participants. The other nine studies involved students from various departments, except for the faculty of education. In only one study, no information about the participants was found. Furthermore, the number of STEAM studies was the same on small and medium scales (N = 6). The number of large-scale learners (N = 2) was small (see **Table 8**). In one study, no information on participant numbers was provided in the reviewed article.

Educational Context

Regarding the educational context of STEAM education in the reviewed studies, we found that STEAM was implemented in different educational contexts. Our first finding is that most studies were conducted in the classroom (N = 13). Only two studies were conducted outside the classroom (Haas et al., 2021; Ifinedo & Burt, 2024). The studies examined included the educational context as a learning environment, such as a face-to-face environment, an experiential learning environment, an informal learning environment, a web-based environment, and augmented/virtual reality (VR) (see **Table 9**). Of the 15 studies, 13 studies were conducted in a face-to-face learning environment, followed by an experimental learning environment (N = 9), an informal learning environment (N = 2), a web-based environment (N = 2), and augmented reality (N = 2).

Table 9. Results on classroom setting and educational contexts

		N
Classroom setting	In classroom face-to-face environment	13
	Out of classroom	2
Educational contexts	Face-to-face environment (i.e., classroom)	13
	Experimental environment (i.e., lab)	9
	Informal learning environment (e.g., museum)	2
	Web-based environment	2
	Augmented/VR	2

Note. N: Number of participants

Educational Effects of STEAM Education Research

Regarding the pedagogical perspective of STEAM education research in schools, we found that all 15 articles examined reported the pedagogical impact and outcomes of applying STEAM education. Specifically, all 15 articles reported on the impact of STEAM on teaching and learning (e.g., learning performance, affective cognition, and higher-order thinking) when applied.

The Effects of Learning Performance

Studies of STEAM teaching have focused on the impact on learning achievement for this group. These studies have examined the effects of implemented STEAM instruction on learner performance by integrating innovative pedagogical approaches into STEAM instruction. For example, Kim et al. (2019) pointed out that an integrated transdisciplinary STEAM instructional approach is based on interdisciplinary research that combines psychology, art, and transformative learning. Their findings showed that their STEAM instructional approach-based teaching is effective at all levels of education because they emphasized that collaborative projects could lead to transformative learning experiences. They concluded that collaboration between art and technology could facilitate teaching in STEAM-based lessons.

In addition, Ji (2021) investigated STEAM-based teaching using VR technology in animation courses. Participants' learning performance regarding final grade and overall score also improved significantly. His study increased the number of student queries and discussions in a virtual learning environment. In another study, Ifinedo and Burt (2024) investigated the pedagogy of service learning (SL) in the STEAM education context, which combines role modeling and experiential learning to improve student's educational attainment, resulting in better academic performance. The results indicate a positive outcome of college students' SL experiences regarding skill development.

Similarly, Breda et al. (2023) investigated the effectiveness of a STEAM-based approach in enhancing student learning outcomes in a mathematics course at a university. Their results showed that the implementation of a STEAM-based approach led to a reduction in the failure rate in mathematics. Finally, Boytchev and Boytcheva (2020) investigated the effectiveness of STEAM education based on gamification in improving college students' learning outcomes and found a positive expectation of student performance. Román-Graván et al. (2020) investigated how educational robotics can empower women and promote gender equality in teacher education. They found that robotics kits in STEAM lessons contributed to female participants having a very positive attitude towards educational robotics before and after the experience. Thus, the results of these studies indicate that the implementation of STEAM education has helped improve college students' learning performance. Kreis et al. (2024) investigated the effectiveness of flipped classroom methods in a STEAM-based educational context to determine the benefits and challenges in a teacher education program. Their results showed that prospective teachers' understanding and academic performance improved significantly in collaborative flipped learning environments. Lin and Chiang (2019) aimed to enhance college students' learning outcomes after using the 6E model in STEAM teaching and found that students' learning outcomes were significant after implementing STEAM-based courses.

To summarize, these studies' results demonstrate the effectiveness of STEAM-based instruction on college student learning outcomes. Studies have shown that implementing STEAM instruction in schools has positively impacted students' learning performance. In addition, various teaching methods, such as flipped classrooms, SL, problem-based learning, and VR, have also positively affected students' academic performance.

The Effects on Affective Factors

Most of the studies we reviewed in this systematic review showed the educational impact of STEAM-based teaching on participants' affective factors such as attitude, self-confidence, engagement, interest, motivation, satisfaction, self-regulation skills, and teamwork. These studies provide more evidence and a comprehensive understanding of how affective factors such as attitude, interest, and motivation influenced participants in STEAM instruction. For example, Hung et al. (2024) found that implementing a STEAM-based assistive technology curriculum significantly influenced student satisfaction. They reported that their participants had positive learning experiences in STEAM-based instruction. Chen and Dong (2023) found that applying STEAM educational concepts in teaching art songs significantly increased students' learning interest and motivation. They also reported that students' interpersonal skills and teamwork statistically improved significantly after their study.

In addition, in a study on STEAM-based instruction using VR technology in animation courses, Ji (2021) found that STEAM-based instruction stimulated students' learning initiative and motivation. Similarly, the findings of Kim et al. (2019) indicated the transformative potential of integrated transdisciplinary approaches to promote a positive learning environment at different levels of education. Ifinedo and Burt's (2024) study found that students' experiences as role models improved their skills and positively influenced their attitudes toward learning and community engagement. Similarly, Breda et al. (2023) found that a STEAM approach in calculus courses can improve students' perceptions of mathematics, increase learning outcomes, and decrease failure rates. Karppinen et al. (2017) investigated integrating interdisciplinary craft design based on STEAM education to improve pre-service teachers' pedagogical skills and foster creativity and practical skills. They concluded that pre-service teachers' attitudes toward interdisciplinary teaching changed positively after STEAM instruction.

Boytchev and Boytcheva (2020) found a positive participant motivation expectation. In another research, Kreis et al. (2024) investigated the effectiveness of flipped classroom methods in a STEAM-based educational context to determine the benefits and challenges of a teacher education program. Their results show that student engagement improved significantly among preservice teachers. They also found that flipped and STEAM-based instruction helped prospective teachers develop significant confidence in applying math concepts and pedagogical principles while acquiring important self-regulation skills. In addition, Breda et al. (2023) investigated the effectiveness of a STEAM-based approach in improving college students' attitudes toward mathematics. Their results showed that implementing a STEAM-based approach led to a positive increase in attitudes. The results of Lu (2021) revealed that participants' learning ability and innovative thinking skills developed after STEAM-based lessons with game-based learning.

The research of Lin and Chiang (2019) used the 6E model in STEAM teaching to increase college students' learning satisfaction. They found that their participants were significantly and positively satisfied with the Internet of technology smart cane creative design STEAM course. An (2020) investigated how integrating STEAM into mathematics methods courses affected prospective teachers' attitudes, confidence, and knowledge. She found that integrating STEAM into mathematics methods, courses engaged the prospective teachers in four steps of the inquiry using the problem-based learning approach. The prospective teachers improved their attitudes and confidence in STEAM integration. Hung et al. (2024) examined the impact of a STEAM-based assistive technology curriculum. Their results showed that a structured educational framework can significantly improve student satisfaction and professionalism. In summary, these studies' results provide evidence of the effectiveness of STEAM-based instruction on learners' affective factors such as attitude, self-confidence, engagement, interest, motivation, satisfaction, self-regulation skills, and teamwork. The studies reviewed demonstrate that the integration of STEAM education has positively influenced learners' educational experiences, creative abilities, satisfaction levels, and motivation.

The Effects of Development Skills

Some research has concentrated on developing undergraduate students' knowledge, skills, and development. For example, Haas et al. (2024) examined the effect of an integrated STEAM approach in designing outdoor learning pathways in teacher education during distance learning due to the COVID-19 pandemic. They defined three different clusters of teaching patterns. In their research, pre-service teachers reported greater engagement and acceptance of STEAM teaching methods, emphasizing the importance of collaborative learning and peer interaction. In addition, their results showed the most incredible engagement with technology. The study of Karppinen et al. (2017) investigated integrating interdisciplinary craft design based on STEAM instruction to enhance pre-service teachers' pedagogical skills and promote creativity and practical skills. They found that pre-service teachers found a new way of thinking and organizing interdisciplinary instruction, discovered new ideas, and found the courage to learn across disciplines, not only in the subjects used here but in any combination of subjects. An (2020) investigated the effects of STEAM instruction in mathematics methods courses that influenced prospective teachers' knowledge. She found that the prospective teachers improved their knowledge of STEAM integration. Finally, Gu et al. (2023) developed a creativity course for college students that included STEAM field integration activities to practice and strengthen creative thinking skills in schools. They evaluated the effectiveness of this course on participants' creativity skills and creativity self-efficacy. The results showed that the participants' creative skills had improved significantly after the course. They also found an increase in creative self-efficacy in the experimental group. These studies show that STEAM instruction positively impacts prospective teachers' professionalism and pedagogical skills, creativity and practical skills, knowledge of STEAM integration, and creative thinking skills.

DISCUSSION

This study analyzed the implementation of STEAM education in schools. The results of this study represent the knowledge and understanding of the educational objectives and empirical results of the implementation of STEAM education. Our results show that all the articles we analyzed were published after 2019. The results show that 2019 was particularly important because the implementation of STEAM education began that year. This result indicates a clear trend towards more research on STEAM education. The number of studies peaked in 2024, in line with Supriyadi et al. (2023). The publication of articles on the implementation of STEAM education after 2019 may be because researchers have focused on STEAM education to enhance learners' creativity and critical thinking through the use of STEAM education to prepare students for real-world challenges and to teach them interdisciplinary approaches (Bertrand & Namukasa, 2020; Sanz-Camarero et al., 2023). In particular, an interdisciplinary perspective integrating STEAM education into curricula has encouraged educators to seek strategies that promote deeper learning and transferable skills (Kelley & Knowles, 2016; Leavy et al., 2023). Furthermore, the rapid advancement of technology has prompted researchers to investigate the impact of STEAM education on the necessary skills of their learners for a digital and connected world (Leavy et al., 2023; Supriyadi et al., 2023).

Second, all of the articles examined used instructional methods to achieve the goals of STEAM education. These instructional strategies included action research, collaborative learning, design-based learning, flipped classroom, game-based learning, hands-on activities, inquiry-based learning, lecture, problem-based learning, PBL, outdoor learning, self-learning, and virtual learning. Almost half of the studies used the collaborative learning method. In three other studies, problem-based learning was used. Learning methods involving the use of technology were implemented with flipped classrooms, game-based learning, and VR methods. The researchers used lectures or traditional methods in the studies, and they used experimental and control groups. Thus, these results indicate that STEAM education was delivered by researchers using different teaching methods. The use of different teaching methods for STEAM education could meet the needs of learners in these studies to convey the essence of STEM subjects in an interdisciplinary learning context (Akhatayeva et al., 2024; Shurygin et al., 2023). The need to adapt to different learning methods may also be another reason to meet student learning objectives in an instructional context. For example, researchers have indicated that PBL is an effective strategy in STEM education to promote problem-solving skills and real-world learning experiences (Wei et al., 2023; Hawari & Noor, 2020; Zhumabay et al., 2024).

Third, our results revealed that the studies were conducted using small (≤ 50) and medium scales (51-300). This finding showed that researchers conducted their research in their classrooms. Fourth, our results concerning the educational context show that most studies were conducted in the classroom. Only two studies were conducted outside the classroom (Haas et al., 2021; Ifinedo & Burt, 2024). Of these studies, the vast majority used a face-to-face classroom environment. Nine of these studies examined the effects of STEAM instruction using experimental teaching. One of the reasons for this finding is that the researchers used experimental teaching to investigate the effectiveness of the teaching they implemented on learning outcomes such as student engagement, creativity, and learning outcomes (Ibraeva & Bayan, 2023; Issayeva, 2024). In addition, two studies used informal learning environments, web-based environments, and augmented reality.

Fifth, the findings regarding the effects of STEAM instruction on learning achievement suggest that these studies emphasize the effectiveness of STEAM-based instruction in improving college students' learning outcomes. Research has shown that STEAM instruction positively impacts student academic performance. In addition, various teaching methods, including flipped classrooms, SL, problem-based learning, and VR, have shown that STEAM instruction positively impacts student academic performance. With this finding, we have well documented the effectiveness of different teaching methods in STEAM instruction in improving student performance in different areas and subjects. This finding can explain the nature of using different teaching methods. For example, inquiry-based learning can develop critical thinking skills, self-efficacy, and understanding of real-world problems because it allows learners to explore problems and develop solutions (Wei, 2023). In addition, project-based instruction can help students take responsibility for their learning and expand their knowledge (Jia et al., 2021).

Sixth, the effects on affective factors have shown that implementing STEAM education can positively and significantly improve school students' affective factors, including attitude, self-confidence, engagement, interest, motivation, satisfaction, self-regulation skills, and teamwork. The studies we examined showed that implementing STEAM education positively influenced learners' learning experiences, creative skills, satisfaction, and motivation. Previous research has shown that STEAM education helps to make the learning experience more engaging for learners. Thus, it has helped them recognize the connections between different subject areas in STEAM fields and apply their knowledge in real-life contexts through the implementation of STEAM instruction, and this type of instruction can increase their motivation, interest, and engagement in learning (Amiruddin et al., 2022; Hsiao & Su, 2021). Using different teaching methods to implement STEAM lessons and the active involvement of learners in the learning process leads students to develop their affective factors, such as self-confidence, creativity, and independence (Degeng, 2021; Zhang et al., 2019).

Finally, these studies demonstrate that STEAM instruction positively impacts prospective teachers' professionalism, pedagogical skills, creativity, practical skills, knowledge of STEAM integration, and creative thinking skills. Thus, the findings show the benefits of STEAM education to support preservice teachers' development. This finding supports the results of previous research indicating that preservice teachers who participate in STEAM-focused education demonstrate improved pedagogical skills and a remarkable ability to integrate different content areas into their teaching practice (Silva-Hormazábal & Alsina, 2023). Studies have shown that pre-service teachers participating in STEAM initiatives demonstrate greater confidence in their pedagogical skills and a more outstanding commitment to interdisciplinary teaching (An, 2020b; Bush & Cook, 2016). This finding underscores the importance of structured development programs that introduce pre-service teachers to STEAM concepts and provide them with the tools and strategies for successful implementation.

CONCLUSION

This systematic review presents a new perspective on implementing STEAM education. Although some research reviews have focused on STEAM education, they have not paid enough attention to implementation. The results regarding the implementation of STEAM education provide a reference point for further research. Researchers can benefit from our findings on the implementation of STEAM education and consider appropriate teaching processes for integrating STEAM. From this perspective, it is important to integrate the different fields closely together to improve college students' learning and affective outcomes. Therefore, our findings provide a theoretical basis for integrating STEAM education in the following studies. The practical contributions of this study include reviewing empirical findings on the implementation of STEAM education for curriculum development and informing researchers about teacher education. This study underscores the positive impact of STEAM instruction on college students. The findings in this research contribute to the literature by presenting new insights for instructors and researchers.

Limitations

There are certain limits to this systematic review's capacity to guide future research. First, although we used only one database, search, and screening bias may occur. Since the implementation of STEAM is possible in many areas of educational research, we may have missed some studies relevant to STEAM. Therefore, future studies should consider this issue and revise their search criteria to consider this in future studies. Second, from the perspective of a systematic review, we used a systematic review analysis using codes and dimensions to examine the characteristics of studies on the implementation of STEAM education. Thus, there is a need to examine and gain a deeper understanding of the implementation of STEAM education. Third, we only used a systematic review in this study. In future studies, researchers should consider a meta-analysis to determine the effect sizes of recent empirical studies to gain a deeper understanding of the implementation of STEAM education.

Recommendations

This study has important theoretical and practical implications for research, and further studies are essential to fill existing research gaps resulting from this research. First, longitudinal studies are needed to examine STEAM-based curricula' long-term effects on learners' outcomes. Future research should include the observation of students over multiple semesters to evaluate the effectiveness of STEAM education. In addition, researchers should examine the skills acquired through STEAM instruction. Another recommendation for future research is to investigate the effectiveness of artificial intelligence in STEAM disciplines. For example, future studies can compare traditional teaching methods with artificial intelligence regarding student learning outcomes and skills. Future studies could examine the effectiveness of mentoring programs in teacher education using STEAM instruction. Furthermore, given that there were 15 articles on the implementation of STEAM, this finding indicates that more systematic research on STEAM education is needed in the coming years. In addition, instructors who teach interdisciplinary courses can design more appropriate STEAM activities for their higher-education students, as research has found positive outcomes for learners. If students are to develop interdisciplinary skills in STEAM education, faculty and researchers should be equipped with the appropriate teaching skills to implement STEAM education. For future studies, it is also necessary to design and implement STEAM activities in schools in a more structured way to achieve a better teaching impact and provide more good examples of STEAM teaching. Finally, despite the importance of STEAM instruction in schools, there is very little research addressing the implementation of STEAM instruction. Implementing STEAM education in teacher education should receive more attention in future studies.

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