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Exploring current thematic and methodological patterns in STEAM education research

Science, Technology, Engineering, Arts, and Mathematics (STEAM) is a recent educational strategy that proposes interdisciplinary teaching, encouraging innovation and economic growth. However, at the stake of this field development, there is a lack of research exploring the recent state of STEAM education research approaches. Therefore, this study aimed to explore the thematic and methodological patterns of recent STEAM education research, and for this purpose performed an in-depth PRISMA-guided systematic literature and content analysis of 20 manuscripts published between 2019 and 2024 in the Taylor & Francis and Emerald databases. The study noticed that research on STEAM education has increased in the past two years, and the qualitative method was the most frequently utilized research design; students and teachers were the primary research participants; however, the experts' and policymakers' perceptions of STEAM education have received little attention. Findings also revealed three categories of themes in current STEAM education research: 1) encouraging meaningful STEAM learning experiences for students, 2) teacher education and 3) understanding STEAM education as a field that requires further in-depth study of its processes. Implications were provided to advance further studies in STEAM education research.

Keywords: STEAM, education, research, patterns, PRISMA, content analysis, systematic analysis, literature review.

Introduction

STEAM is a latest educational approach that advocates integrated teaching of science, technology, engineering, arts, and math (Rodrigues-Silva & Alsina, 2023) [1]. In 2013 the US adopted a resolution "that adding Art and Design into Federal programs that target the Science, Technology, Engineering, and Mathematics (STEM) fields encourages innovation and economic growth in the United States" (US Government Publishing Office, 2013:1) [2]. Since that time STEAM has acquired its significance in educational discourse. In particular, the review of empirical studies suggests that the research on STEAM education has progressed within the last ten years. Studies emphasize specific aspects and issues in STEAM education. For example, Bequette and Bequette (2012) [3] believe that blending arts and science may lead to a synergistic interaction and increased student engagement. The case study conducted by Henriksen (2014) [4], who interviewed the most successful teachers to explore their creative teaching techniques, showed that arts-based education enhances enthusiasm, involvement, and successful learning in STEM disciplines and enables students to get superior outcomes.

Additionally, Land (2013) [5] suggests that STEAM education could promote communication and collaboration among students. Furthermore, researchers like Perignat and Katz-Buonincontro (2019) [6] highlight that STEAM programs increase the involvement of females and minorities. Another study done by Yakman and Lee (2012) [7] confirms that STEAM by teaching students on cognitive skills needed to be adaptive lifelong learners helps prepare children to comprehend the changes they will experience in their lives. However, at the high stake of this field development, there are lack of studies exploring the current state of existing STEAM education research approaches, purposes, and thematic focus. Such an overview may give an expanded assessment of evidence for stakeholders, practitioners, and scholars, as well as allow them to study patterns and changes in research over time (Polanin & Dell, 2017) [8]. Thus, this research aims to answer the following research question: What are the recent thematic and methodological patterns in STEAM education research? To answer this question, the study first determines the frequency of publications in the previous five years, the range of journals that issue STEAM education research, and the allocation of papers by design of the study, respondents, research goal, and conceptual focus.

The literature reports STEAM education research has progressed within the last decade. Studies focus on specific aspects and issues in STEAM education, such as conceptualizing and defining the term (Perignat

& Katz-Buonincontro, 2018; Rodrigues-Silva & Alsina, 2023) [6], [1], discussing STEAM education's role in nurturing early childhood education (Wahyuningsih et al., 2020) [10], enhancing student creativity (Aguilera & Ortiz-Revilla, 2021) [11], encouraging teacher professional development (Monkeviciene et al., 2020) [12], digital competencies for sustainable innovations and computational pedagogy (Deák & Kumar, 2024; Hyun & Park, 2020; Psycharis, 2018) [13], [14], [15]. Some researchers attempted to investigate advancements in STEAM research; and for this purpose, employed bibliometric and systematic reviews. For example, Pahmi et al. (2022:93) [16] did a bibliometric review of 35 manuscripts published between 2012 and 2021. The study found STEAM education is closely related to the project-based learning method, and significantly enhances problem-solving (Pahmi et al., 2022) [16]. Santi et al., (2021) [17] investigated patterns of STEAM in science education and conducted a bibliometric mapping of literature. They examined 30 Scopus papers from 25 prominent journals dated from 2013–2020. Study findings indicated that South Korea is emerging as the most frequently published country, and that such themes as STEAM education, engineering education, education computers, and students are the most commonly explored subjects by researchers (Santi et al., 2021) [17]. Similarly, Marín-Marín et al. (2021) [18] undertook a study to assess the progress of STEAM-EDU in scientific publications. The concept STEAM was reviewed in the Web of Science database utilizing the WoS programs. The research methodology employed in the paper was bibliometric. They conducted a co-word analysis of 1116 works published between 2006 and 2020 (Marín-Marín et al., 2021:1) [18]. Findings suggest STEAM-EDU research follows an established pattern, although new fields of inquiry are emerging. In contrast to Santi et al. (2021) [17], Marín-Marín et al. (2021) [18] discovered that the United States is the leading generator of publications in this field of research. J. Bazler and M. Vansickle were discovered to be the most famous researchers in the subject, having authored the most manuscripts (14 each) in STEAMEDU study (Marín-Marín et al., 2021:16-17) [18]. In addition, STEAM research investigates gender inequalities, its impact on diverse populations, student skill development, and teacher preparation for STEAM-based teaching and learning. Furthermore, Nurdiyanso et al., (2023) [19] analyzed 9 publications extracted from Scopus published between 2013 and 2023 applying meta-analysis. This review discovered that such factors as instructor and student attitudes, and educating talent influence STEAM education. Additionally, findings demonstrated positive STEAM learning outcomes at elementary, junior high, and high school levels of education (Nurdiyanso et al., 2023) [19]. In particular, the study confirms a correlation between STEAM education and improved thinking skills among Indonesian pupils. A paper by Zhao (2022) [20] explored research trends in both STEAM and STEM education and reviewed 495 papers published in 16 top journals from 2016 to 2021. The findings reveal a significant rise in STEM education research since 2016. Although STEAM education has fewer publications than STEM, it is rising more rapidly than STEM education. STEAM/STEM goals, motivations, evaluation, policy, curriculum, assessment, teaching, teacher education, and learning are some of the most commonly explored themes (Zhao, 2022:162) [20].

Prior literature is valuable for identifying the overall research trends, but these studies are limited in shedding light on the aims of STEAM research, and its recent overall thematic and methodological patterns. They are also limited in the range of publications, databases, and timeline included for the analysis.

Therefore, to fill the existing gap this study conducts a systematic review of the international empirical literature and explores recent STEAM education research. For this purpose, the study identifies the research purpose, methodological patterns, and thematic focus of recent STEAM education research. This might be useful in proposing valuable outlooks and perspectives for further STEAM research.

Methods and materials

Publications were selected following the PRISMA principles methodology (Page et al., 2021) (see Fig. 1) [9]. To the best knowledge of the author, there is a lack of studies that investigated STEAM education research within the last five years that applied PRISMA methodology to identify the research purpose and methodological and thematic patterns. The data were collected from Taylor & Francis and Emerald databases. Selected research included peer-reviewed publications and high-quality empirical journal articles published in the English language within the last five years from 2019 to 2024. The acronym STEAM (Science, Technology, Engineering, Arts, and Mathematics) was employed as the concept in search of publications' titles, abstracts, and keywords. Each database was run using the STEAM concept in the advanced search. The main subject for STEAM research analysis was education, which was employed as a term in the search filter (see Table 1).

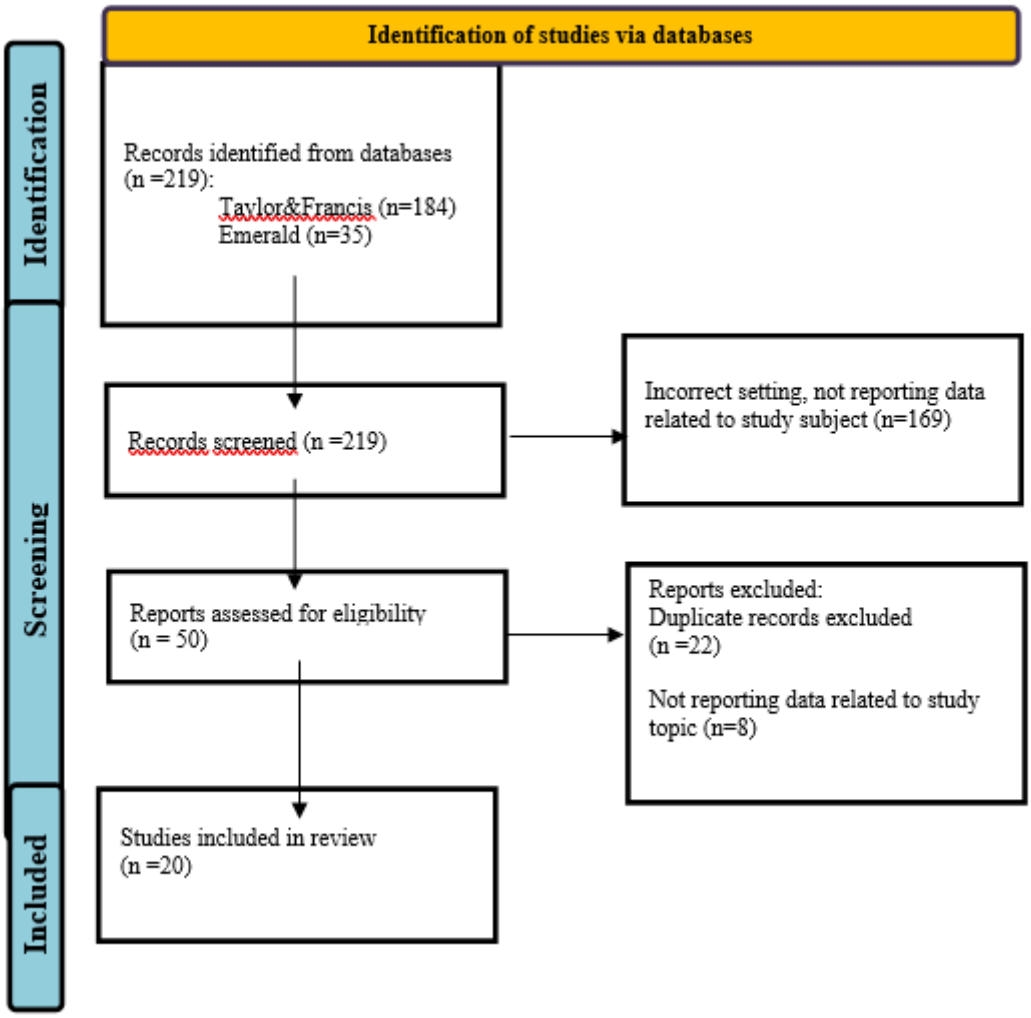

Figure 1. PRISMA flow diagram compliant with PRISMA 2020 statement (Page et al., 2021) [9]

Overall, 219 records were identified from two databases. Specifically, in the total of 59 articles were found where the concept appeared in the articles' title, 67 articles in the abstract, and 58 in keywords; totaling 184 articles extracted from the Taylor & Francis database. The same principle was employed for the Emerald database search: 9 articles were found with the STEAM concept appearing in the title, and 26 in the abstract, totaling 35 identified records. As a result of the records screening, abstract analysis, and assessment for eligibility, 199 articles were excluded due to incorrect seating, duplication, and not reporting data related to the study topic and subject. In total 20 papers were identified that satisfied the inclusion criteria among 219 sources and were subject to in-depth content analysis.

Table 1

Inclusion and exclusion criteria

Inclusion criteria		**Exclusion criteria**
Dimension	Designation	Publications published until 2018 Publications from non-peer-reviewed journals and grey literature
Year of publication	2019–2024	
Databases	Taylor & Francis (https:/www.tandfonline.com/) Emerald (https://www.emerald.com/insight/)	
Types of document	Articles published in peer-reviewed journals	

Continuation of Table 1

Inclusion criteria		Exclusion criteria
Dimension	Designation	Editorials, book reviews, conference proceedings, expert briefings Publications published not in English, and non-education-related subjects
Subject	Education (article demonstrates use of STEAM in formal education in practice and/or theory)	
Search words	STEAM (Science, Technology, Engineering, Arts, and Mathematics; concept appears in the article's title, abstract, and keywords)	
Language	English	

Results and discussion

The study's goal was to explore the thematic and methodological patterns of STEAM education research. For this reason, a PRISMA-guided systematic literature review of 20 manuscripts published between 2019 and 2024 in the Taylor & Francis and Emerald databases was performed. Table 2 shows the list of articles that were selected for in-depth analysis. Figure 2 shows the frequency of publications by year and an increase in STEAM education-related studies in 2023 and 2024 (n=8; n=4) compared to earlier years. Similarly, Zhao (2022) [20] who explored research trends in STEAM and STEM education found that research on STEAM is rising rapidly.

Table 2

Sampled studies

ID	Studies (1–10)	ID	Studies (11–20)
S1	Bertrand and Namukasa (2023) [21]	S11	Ben-Horin et al. (2023) [31]
S2	Chen et al. (2019) [22]	S12	Salmi et al. (2023) [32]
S3	Gonzalez (2022) [23]	S13	Perales and Aróstegui (2024) [33]
S4	Bertrand and Namukasa (2020) [24]	S14	Magnusson and Bäckman (2023) [34]
S5	An (2020) [25]	S15	Loumpourdi (2024) [35]
S6	Romero-Ariza et al. (2021) [26]	S16	Yunianto et al. (2024) [36]
S7	Belbase et al. (2022) [27]	S17	Roughley et al. (2019) [37]
S8	Santos et al. (2023) [28]	S18	Hilppö and Stevens (2023) [38]
S9	Laksmiwati et al. (2024) [29]	S19	Ross et al. (2023) [39]
S10	Malagrida et al. (2022) [30]	S20	Laksmiwati et al. (2023) [40]

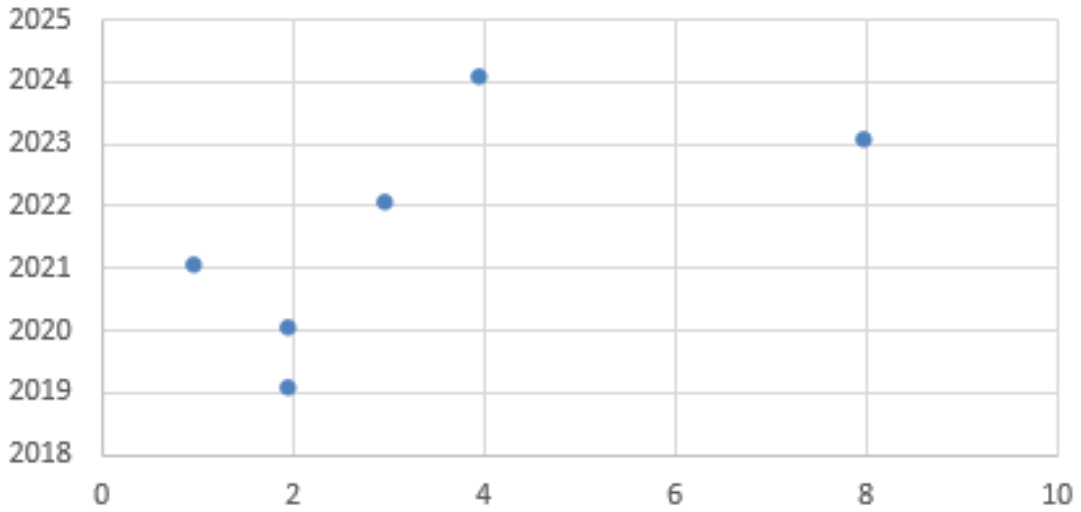

Figure 2. The publications' frequency

Table 3

A total of 16 selected journals with STEAM education studies

No	Journal name	# of publications
1	Journal of Research in Innovative Teaching & Learning	4
2	Cogent Education	2
3	Asian Association of Open Universities Journal	1
4	Journal for the Study of Education and Development	1
5	International Journal of Mathematical Education in Science and Technology	1
6	Educational Media International	1
7	Asia Pacific Journal of Education	1
8	Research in Science & Technological Education	1
9	Interactive Learning Environments	1
10	Arts Education Policy Review	1
11	Early Years	1
12	Journal of Vocational Education & Training	1
13	Science Activities	1
14	Higher Education Pedagogies	1
15	Education 3–13	1
16	Environmental Education Research	1

Table 3 shows a list of publications featuring STEAM education research. Table 4 illustrates the distribution of publications by study design, and suggests that qualitative study design was the most frequently employed research approach by scholars (60 %), followed by the mixed and multi-methods approach (25 %). Among them, the quantitative and other designs were used least frequently (15 %). This suggests that there is a lack of quantitatively examined STEAM education research. In addition, the study reveals that various types of qualitative methods were employed; qualitative case studies, ethnography, narrative analysis, and

literature reviews were the most common methods applied by the researchers. One explanation for this could be the reason that qualitative methods are useful in exploring recent or less researched areas of research to build fundamental knowledge, where previous knowledge is less available (Aspers & Corte, 2019; Levitt et al., 2018) [41], [42].

Table 4

The distribution of publications by study design (2019–2024)

Study design	Methods	%	Study ID
Mixed and mutli-methods (f=5)	Case study: teaching design, process analysis, self-evaluation and peer evaluation forms	25	S2
	Case study: longitudinal analysis, qualitative reflections		S3
	Pre-and post-surveys, open-ended questions with thematic and tasks analysis		S5
	Quasi-experimental pre-test/post-test design, qualitative reflections		S6
	Design-based research: teacher's workshops, pre-test/post-test surveys, classroom observations, reflection notes		S8
Quantitative (f=2)	Quasi-experimental: surveys	10	S12
	Workshops, surveys		S9
Qualitative (f= 12): Empirical (f=7) Desk research (f=5)	Qualitative case study: interviews, lesson observations, document analysis	60	S1
	Qualitative case study: observations, interviews, document analysis		S4
	Ethnography: studio observations, semi-structured interviews		S18
	Interviews, narrative analysis		S19
	Exploratory case study: semi-structured interviews, document analysis		S20
	Educational-design research: lessons design+ modelling+reflections		S16
	Literature review, focus group discussions		S10
	Literature review, document analysis		S7
	Literature review		S11
	Literature review		S13
	Literature review (meta-study)		S14
	Literature review		S15
Other (f=1)	Practice-based research: studio practice, student projects, workshops, modules, roundtable	5	S17

Notably, students and teachers were the research participants in most studies (36 %). 29 % of studies were explored solely from teachers' and 14 % from students' perspectives. Students, teachers, and directors participated jointly in 14 % of STEAM education research. Interestingly, only one study jointly involved the views of practitioners, experts, and policymakers, which implies that these stakeholders' understanding of STEAM education has been scarcely studied (see Table 5).

Table 5

The distribution of publications by research participants (2019–2024)

Research participants	f	%	Study ID
Students+teachers+directors	2	14	S1, S4
Students	2	14	S3, S12
Teachers	4	29	S5, S6, S9, S10
Students+teachers	5	36	S2, S8, S16, S18, S19
Practitioners+experts+policymakers	1	7	S20
Total	14	100	S1, S4, S3, S12, S5, S6, S9, S10, S2, S8, S16, S18, S19, S20

Furthermore, this study reveals that there are three categories of thematic focus in STEAM research: a) meaningful STEAM learning experience for students, b) teacher education and professional development, and c) understanding STEAM education (see Table 6). In particular, results indicate that current research on STEAM education is mainly focused on understanding how to facilitate meaningful STEAM learning experiences for students (40 %). This is related to investigating scholars' pedagogical models and instructional programs for meaningful math learning, learning STEAM online, developing students' transferable, interdisciplinary, and trans-disciplinary STEAM skills, fostering students' participatory citizenship, assessing cognitive learning outcomes, integrating CT, and fostering interest-driven creativity. Next, teacher and employment education (30 %) were identified as the second category. Most studies concentrated on examining the impact of STEAM on teachers' beliefs, performance, planning of the lessons, and developing research competence realization in STEAM. Understanding STEAM education (30 %) was another category that emerged from the content analysis. Researchers within this category investigated the prospects, processes, and problems of current STEAM education. Compliant with previous research (Aguilera & Ortiz-Revilla, 2021; Monkeviciene et al., 2020) [11], [12], concentrating on students' skill development and teacher preparation was found as a prevailing focus among STEAM education scholars. However, this research reveals that in addition to teachers' and students' knowledge development, exploring STEAM education as an emerging field (processes, principles, and priorities) is another topic that interests the research community.

Table 6

Review results by research purpose and thematic focus (2019–2024)

Thematic focus	Sub-themes	Research purpose	f	%	Study ID	Year
Meaningful STEAM learning experience for students	Learning of mathematics	To propose and investigate a pedagogical model for meaningful math learning	8	40	S1	2023
	Learning STEAM online	To provide references for teachers			S2	2019
	Developing transferable, interdisciplinary, trans-disciplinary STEAM skills	To describe how synergies between research and business plan competitions can promote student inclusion			S3	2022
		To understand the STEAM instructional programs by nonprofit organizations			S4	2020
	Fostering students' participatory citizenship	To understand how STEAM interdisciplinary activities may promote students' participatory citizenship			S8	2023

Continuation of Table 6

Thematic focus	Sub-themes	Research purpose	f	%	Study ID	Year
Meaningful STEAM learning experience for students	Assessing cognitive learning outcome	To identify influential variables that promote cognitive learning	8	40	S12	2023
	Integrating CT	To identify instances of learners' creative actions			S16	2024
	Fostering interest-driven creativity	To theorize and foster interest-driven engagement and creativity			S18	2023
Teacher education and professional development	Pre-service teachers' disposition	To examine the impact of STEAM on pre-service teachers	6	30	S5	2020
	Secondary education teacher professional development	To understand the effect of STEAM courses on teachers' beliefs, performance			S6	2021
	Teacher professional development	To study how the iterative design affected the planning of the lessons			S9	2024
		To develop "responsible research and innovation" implementation in STEAM			S10	2022
		To model a meta-approach to feature arts in STEAM			S14	2023
	Employees education	To investigate skill advancement for 4IR manufacturing employees			S15	2024
Understanding STEAM education	Prospects, priorities, processes, pedagogic principles and problems	To learn the current state of STEAM education	6	30	S7	2022
		To formulate an integrated set of pedagogic principles in STEAM education			S11	2023
		To review the necessity of combining STEAM with arts in school curricula			S13	2024
		To explain the case of the MA Art in Science program			S17	2019
		To study the experience of STEAM-related climate change education projects in rural Wales			S19	2023
		To investigate how STEAM education is put into action in Indonesia			S20	2023

Conclusion

This systematic review aimed to identify and categorize the methodological and thematic patterns of STEAM education research within the last 5 years. The research included an in-depth content analysis of peer-reviewed publications published in the English language from 2019 to 2024 that were selected according to PRISMA methodology principles. Furthermore, a qualitative study design was the most frequently employed research approach by scholars. The study revealed that students and teachers were the main research participants in most studies; however, practitioners, experts and policymakers' perceptions of

STEAM education have been scarcely studied. This study has also revealed that there were three categories of themes in STEAM research: a) encouraging meaningful STEAM learning experiences for students, b) teacher education and professional development, and c) understanding STEAM education as a field that requires further in-depth study of its processes, principles, priorities, opportunities, and challenges.

The perspectives for further STEAM education research could be to diversify research approaches in studying the field and employ a variety of methods, including quantitative and mixed-methods study designs. Studying STEAM education from the lens of different stakeholders, such as managers, practitioners, and policymakers, and comparing these with teachers' and students' perspectives could enrich further study findings and bring more diversified views. It is hoped that future research in STEAM education will keep growing, therefore it would be useful to evaluate patterns in the next 10 years.

This review focused only on journal articles with full access published in the English language based on two databases, therefore further research could survey editorials, book reviews, conference proceedings, and expert briefings, and enlarge the scope of research by including studies available in other languages and sources.

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STEAM-білім беру саласындағы зерттеулердің тақырыптық-әдістемелік бағыттарына жүйелі шолу

Ғылым, технология, инженерия, өнер және математика (STEAM) — инновация мен экономикалық өсуді ынталандыратын пәнаралық оқытуды ұсынатын соңғы білім беру стратегиясы. Алайда, осы саладағы зерттеулердің дамуына қарамастан, STEAM-білім берудің зерттеу тәсілдерінің, мақсаттары мен тақырыптық бағыттарының соңғы жағдайын зерттейтін зерттеулердің жетіспеушілігі байқалады. Сондықтан бұл зерттеу STEAM-білім берудегі соңғы зерттеулердің тақырыптық және әдістемелік бағыттарын зерттеуге бағытталған және осы мақсатта Taylor & Francis және Emerald дерекқорларында 2019-2024 жылдар аралығында жарияланған 20 зерттеу мақаласының PRISMA әдістемелерін пайдалана отырып, әдебиеттерге терең жүйелі шолу жасалды. Зерттеу соңғы екі жылда STEAM-білім беру зерттеулерінің артқанын көрсетті; сапалық тәсіл ең жиі қолданылатын әдіс; студенттер мен оқытушылар зерттеудің негізгі қатысушылары болды, дегенмен сарапшылар мен саясаткерлердің STEAM-білімін қабылдауы, ол жайлы ойлары толық зерттелмеген. Нәтижелер сонымен қатар STEAM-білім берудегі ағымдағы зерттеулерде тақырыптардың үш санаты бар екенін көрсетеді: 1) студенттерге арналған STEAM-оқыту тәжірибесін зерттеу, 2) педагогикалық білім және 3) STEAM-білім беруді оның процестерін, принциптерін, басымдықтары мен мәселелерін одан әрі терең зерттеуді қажет ететін сала ретінде түсіну. Автор STEAM-білім беру саласындағы қосымша зерттеулерді ілгерілету үшін тұжырымдар келтірген.

Кілт сөздер: STEAM, білім беру, жүйелі шолу, контенттік талдау, PRISMA, бағыт, зерттеу, әдебиетке шолу.

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Тематические и методологические направления исследований в области STEAM-образования: систематический обзор литературы

Наука, технологии, инженерия, искусство и математика (STEAM) — это недавняя образовательная стратегия, которая предлагает междисциплинарное обучение, поощряющее инновации и экономический рост. Однако, несмотря на развитие исследований в этой области, наблюдается недостаток работ, изучающих недавнее состояние исследовательских подходов, целей и тематической направленности образования STEAM. Поэтому данное исследование было направлено на изучение тематических и методологических направлений недавних исследований образования STEAM, и с этой целью был проведен углубленный систематический обзор литературы с использованием методологий PRISMA, охватывающий 20 исследовательских статей, опубликованных в период с 2019 по 2024 год в базах данных Taylor & Francis и Emerald. Анализ показал, что исследования образования STEAM увеличились за последние два года; качественный подход был наиболее часто используемым методом; студенты и преподаватели были основными участниками исследования, хотя восприятие образования STEAM экспертами и политиками почти не изучалось. Результаты также показали, что в текущих исследованиях STEAM-образования есть три категории тем: 1) изучение опыта обучения STEAM для студентов, 2) педагогическое образование и повышение квалификаций и 3) понимание STEAM-образования как области, требующей дальнейшего глубокого изучения его процессов, принципов, приоритетов и проблем. Сформулированы выводы для продвижения дальнейших исследований в области STEAM-образования.

Ключевые слова: STEAM, образование, систематический анализ, контентный анализ, PRISMA, направления, исследование, обзор литературы.

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