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AG EDITOR

REVIEW

Exploring Trends Topic on Steam Education in Elementary Schools Over the Last Decade: A Bibliometric Analysis

Exploración de las tendencias en materia de educación STEAM en las escuelas primarias durante la última década: un análisis bibliométrico

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ABSTRACT

Introduction: at the elementary school level, STEAM education as a further development of STEM is increasingly recognized as a transformative approach that offers several benefits.
Method: the study used a type of analysis called a bibliometric analysis, which looks at the data in the Scopus database and gives us data about publication details, the countries and institutions involved, the authors who contributed the most, and the main trends in STEAM learning at elementary level. A study of 68 studies published between 2015 and 2024 using VOSviewer software.
Results: the study discovered that the United States is at the top of the list for several amount of research on this issue. Clemson University in the USA has published the highest number of articles on this topic. Herro, Daniel, from Michigan Technological University in the USA, wrote the most papers on this issue that other researchers have cited most often.
Conclusions: two recommended research trends are the integration of AI-based STEAM-based mobile learning and its impact on the cognitive load of elementary education students. Second, the integration of art aspects in robotics-based STEAM learning in elementary education is worthy of further study. These findings are of significant interest to the research community who want to explore further about STEAM in Elementary School.

Keywords: Trends Topic; STEAM; Elementary School Student; Bibliometric.

RESUMEN

Introducción: en la escuela primaria, la educación STEAM, como evolución de la educación STEM, está ganando cada vez más reconocimiento como enfoque transformador que ofrece numerosas ventajas.
Método: el estudio utilizó un tipo de análisis denominado «análisis bibliométrico», que examina los datos de la base de datos Scopus y nos proporciona información sobre los detalles de las publicaciones, los países y las instituciones implicados, los autores que más han contribuido y las principales tendencias en el aprendizaje STEAM en la enseñanza primaria. Estudio de 68 estudios publicados entre 2015 y 2024 utilizando el software VOSviewer.

Resultados: el estudio descubrió que Estados Unidos encabeza la lista en cuanto al número de investigaciones sobre este tema. La Universidad de Clemson, en Estados Unidos, ha publicado el mayor número de artículos sobre este tema. Herro, Daniel, de la Universidad Tecnológica de Michigan, en Estados Unidos, es el autor de los artículos sobre este tema más citados por otros investigadores.
Conclusiones: dos tendencias de investigación recomendadas son la integración del aprendizaje móvil basado en STEAM y la IA, y su impacto en la carga cognitiva de los alumnos de educación primaria. En segundo lugar, merece la pena seguir estudiando la integración de aspectos artísticos en el aprendizaje STEAM basado en la robótica en la educación primaria. Estos hallazgos son de gran interés para la comunidad investigadora que desea profundizar en el estudio de STEAM en la escuela primaria.

Palabras clave: Tema de Tendencia; STEAM; Estudiante de Primaria; Bibliométrico.

INTRODUCTION

Education today needs skills in science, technology, engineering and maths (STEM) to solve complicated problems, and these skills ideally need to be developed from primary school level.[1]

STEM (Science, Engineering, Technology, Mathematics) education is one form of innovation that is considered suitable for implementation in education in the 5.0 era because STEM learning can be effectively applied to online technology and is effective in developing students' science and technology literacy.[2,3]

STEM activities are aimed at forming students who are not only cognitively smart, but also have skills.[4] STEM education can be viewed broadly as encompassing all STEM disciplines, including science, mathematics, technology, engineering, and combinations of these disciplines.[5]

STEM learning began to be widely applied in education since the beginning of 2001 by the National Science Foundation in the United States.[6] STEM learning then began to be developed so that many variations of new approaches emerged by integrating new dimensions to STEM according to trends and needs in the world of education. STEAM learning is a further development of the pure STEM learning version by adding elements of art, which in this case is also referred to as STEM+art.[7,8]The art component was chosen to be further integrated with STEM because art can be a universal STEM learning instrument, and can increase motivation while stimulating students' creative thinking skills.[8,9]

At the primary school level, STEAM education is increasingly recognized as a transformative approach that offers several benefits. By integrating STEAM education into our curriculum, we aim to cultivate students' critical thinking skills and problem-solving capabilities; integrating the arts into STEM fields encourages creativity and innovation; promotes interdisciplinary learning; and supports the development of important nontechnical skills such as collaboration, communication and leadership.[10,11,12,13,14]

However, effective implementation of STEAM education requires teachers to be well prepared and trained in new pedagogical models and methodologies.[15,16]

In some countries, the most pressing problem is the minimum of adequate technological infrastructure, including internet access and digital devices. This is compounded by inadequate training for teachers to effectively use technology in STEAM education.[17,18,19] Effective implementation requires hands-on learning, integration with other subjects and the use of technology.[20,21,22] Addressing challenges related to teacher preparedness and curriculum design can further strengthen STEAM education, preparing students to be innovative thinkers and problem solvers in the 21st century.

Lots of authors are interested in bibliometric methods right now. There are numerous studies that analyse STEM education using well-known databases such as Web of Science (WoS) and Scopus. A bibliometric study analyzed 30 articles from 25 leading journals over an 8-year period (2013-2020) using the Scopus database and VOSviewer software. The report identified South Korea as the most productive country in STEAM research and highlighted key topics such as STEAM education, engineering education, and educational computing.[23] Another study conducted [24] provided a review analyzing 223 articles from the WoS database, showing diverse behaviors and trends in STEAM education, especially those driven by the COVID-19 pandemic. And most recently, A Bibliometric Analysis study of STEAM in Basic Education from 2010 to 2024 [25] this latest report indicates a substantial increase in research activity on early 2016, with the USA and UK demonstrating a notable leadership in academic outcomes.

This study aims to identify, review, and conducting bibliometric analysis of previous trending study on STEAM education in elementary school in the last 10 years. This study will discuss in detail the synthesis of research topics that have been widely studied and potential research topics for future.

METHOD

Research Design

In this research, we used a bibliometric study on STEAM education in Elementary Schools publication on

Scopus database between 2015 until 2024. Metric information collected including: author data, country of origin, article source, citations, and keywords.

Following this, there are three stages in the data collection process to generate data according to the required criteria. The first step is acquiring the data, continuing with reviewing data, and cleansing data.

Acquiring the data

We collecting some publication database from Scopus (http://www.scopus.com) using the advanced search option. The search focused on STEAM-ES, with the data limited to journal articles-only publication. These publications were published in English during 2015 to 2024.

Reviewing and Cleansing Data

The search sequence on the Scopus database is presented in figure 1. After looking through all the articles, we got rid of some that didn't have the right information.

TITLE-ABS-KEY ("STEAM" AND "elementary" AND "student" OR "school") AND PUBYEAR>2015 AND PUBYEAR<2024 AND PUBYEAR>2015 AND PUBYEAR<2024

We reviewed data by screening titles, abstracts, and keywords. We compared authors and found irrelevant or loosely related documents. We eliminated documents with inaccurate or partial searches, single STEAM subjects, and insufficient information. We put information from 208 documents into CSV files and analyzed them with VOSviewer and Excel. We also gathered information on authors, countries, and journals using Scopus and SCIMAGOJR. Finally, we cleaned the data because poor data quality impacts analysis results. Problems included different names for the same institution and authors using different names.

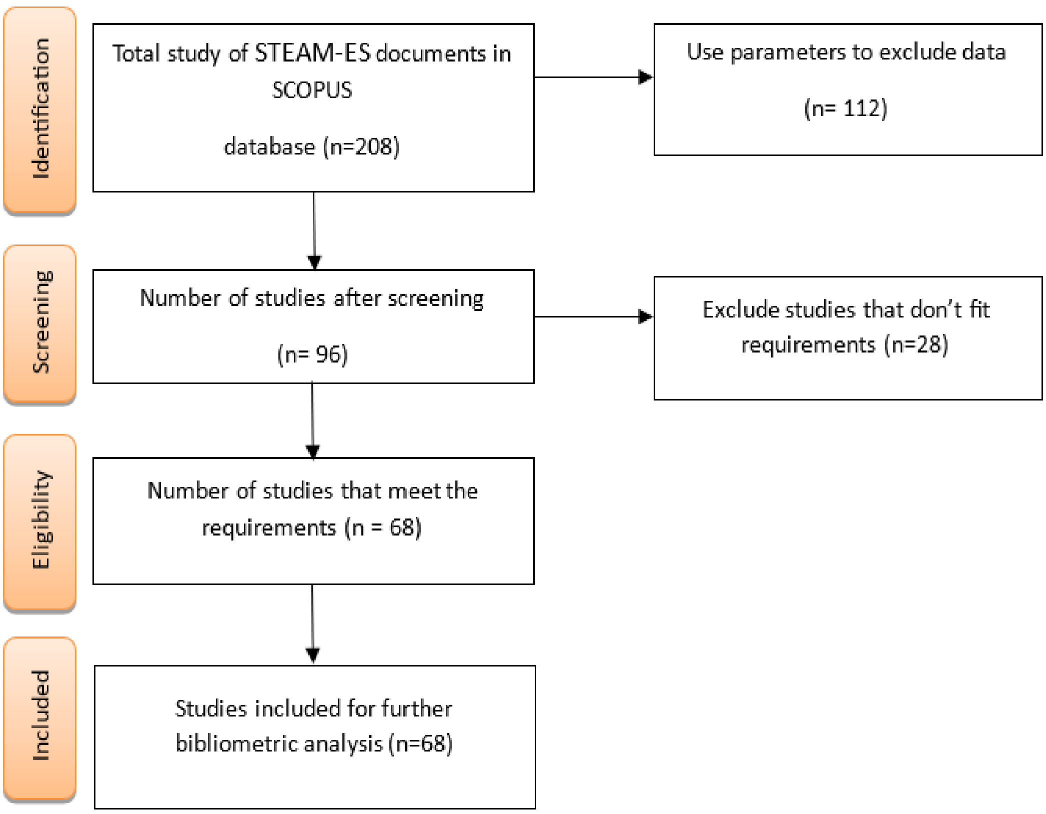

Figure 1. The PRISMA flowchart illustrates the systematic process of data filtration

During the analysis and display of the data, a variety of techniques were used to extract key findings from the data set to demonstrate trends in research growth over time. The comprehensive data analysis is provided in the Results and Discussion section which includes: Growth trend of STEAM-ES publication, the most publication countries on STEAM-ES, the most publication sources on STEAM-ES, top author of STEAM-ES, the most occurrence keywords of STEAM-ES Publication, and review of most-cited articles.

RESULTS

General Information and Growth Trend

Statistics show that a total of 68 documents have been published through 56 sources, reflecting an annual increase of 1,2 % over 2015 to 2024. There were 241 authors involved in research and publications related to this topic; with an average author collaboration per document of 0,47. In this bibliometric study, there were 244 keywords generated by the authors. The publications cited a total of 3028 references. All documents analyzed were scientific journal articles (68). The average citations per document was 14,5, with 21 documents each having been cited minimum 21 times (h-index = 21). All information is described in table 1.

Table 1. Summary of the main data

Explanation	Result
Timeline	2015:2024
Journal Sources	56
Documents	68
Yearly Growth Rate (%)	1,2
Average citations/Doc	14,5
References	3028
Author's Keywords	244
Authors	241
Co-Authors/Doc	0,47
Scientific Article	68
H-index	21

Figure 2 presents provide the count of publications and accumulated citations per year between 2015 and 2024. The average publication on STEAM-ES is 6,8 per year. However, the quantity of publications and citations of STEAM-ES is not consistent from year to year. Between 2015 to 2016 the number of publication and citation remain low. Starting 2017 publication and citation increase until begin to decrease again in 2019. Between 2020 and 2024, the number of publications was peaked. In contrast, the number of citations keep decreasing after hit the peak on 2020.

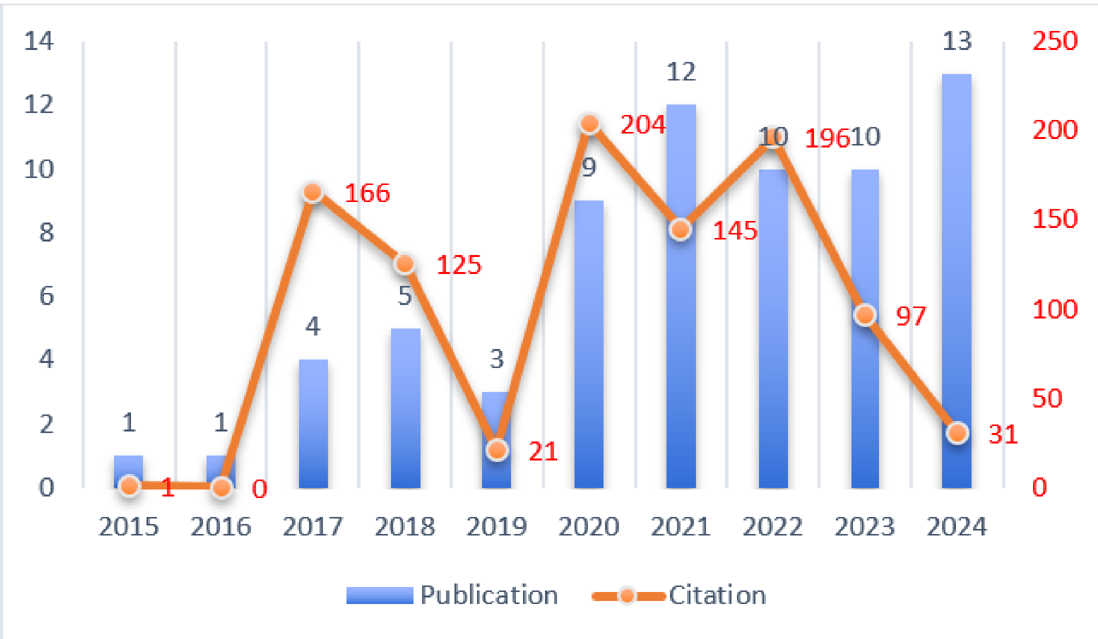

Figure 2. Growth trends of STEAM-ES

Contribution by Nations

Authors from 21 countries have conducted research on this topic. Table 2 shows the main 8 countries with the greatest quantity of publications and citations. These Nations produce 65 articles out of the total 78 compiled (equivalent to 83 %). Among these countries, the United States has more articles than any other region, contributing 17 articles with 496 citations. In this case, Asian countries dominate publications on STEAM-ES, namely South Korea, Indonesia, Taiwan, China and Malaysia with a total of 42 publications.

Table 2. A The list of leading countries on STEAM-ES

Rank	Country	P	C	C/P
1	USA	17	496	29,1
2	South Korea	16	139	8,7
3	Indonesia	13	119	9,2
4	Taiwan	7	182	26,0
5	China	4	69	17,3
6	Spain	3	43	14,3
7	Portugal	3	3	1,0
8	Malaysia	2	3	1,5
Total		65	1054	107,1

VOSViewer was used to make international collaboration maps on this topic. The bibliographic criteria were met by at least two documents per country. Eight countries met the criteria, and six of them collaborated (figure 3). Scientists from the United States most collaborated with three Asian countries: Indonesia, South Korea, and China.

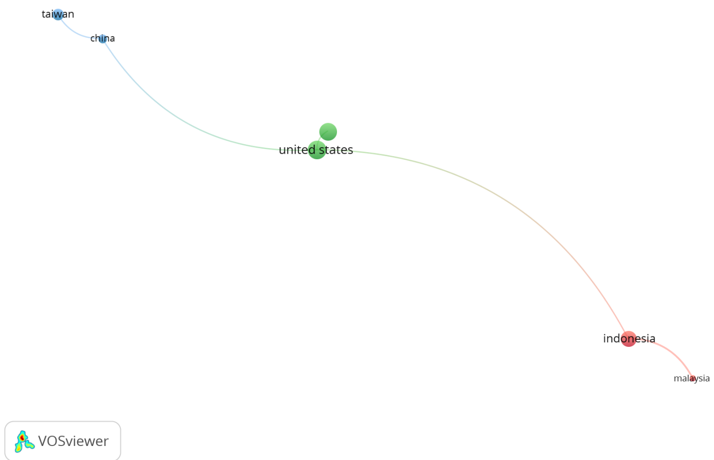

Figure 3. Countries Collaboration on STEAM-ES

Constribution by article sources

The 56 different sources where the studies were published are listed in the bibliography. According to the most recent data, the top five sources of publication are shown in table 3. It is noteworthy that the publications from Q4 sources represent a significant proportion of the total publications listed in the bibliography.

Table 3. The 10 most frequently publishing sources

Rank	Source	P	C	Scopus Quartile	Citescore (2023)	SJR (2023)
1	Frontiers in Education	3	26	Q3	2,9	0,627
2	International Journal of STEM Education	2	157	Q4	12,4	2,035
3	Frontier in Psychology	2	55	Q4	5,3	0,8
4	International Journal of Technology and Design Education	2	49	Q4	5,3	0,812
5	International Journal of Mobile and Blended Learning	2	18	Q3	3,3	0,417

Table 3 shows that 11 articles (16 %) from the five sources were included in the bibliography, which has 305 citations of these sources (31 % of 986 total citations). The International Journal of STEM Education has the highest CiteScore and SJR.

Contribution by author

As shown in table 4, the six researchers who contributed the most out of the 240 author study in this field. The United States is the native country of most of the authors, with five coming from different universities. Daniel Herro is the most productive author in the field of STEAM-ES, with four publications and 155 citations.

Table 4. Top 6 Authors of STEAM-ES

Rank	Author	Affiliation/ Country	P	C	C/P
1	Herro, Daniel	Michigan Technological University/ US	4	155	38,7
2	Quigley, Cassie	University of Pittsburgh/ US	3	111	14
3	Cook, Kristin	Bellarmine University/ US	2	116	2
4	Bush, Sarah B.	University of Central Florida/ US	2	116	58
5	Plank, Holly	Bowling Green State University/ US	2	55	23,5
6	Rahmawati, Yuli	Universitas Negeri Jakarta/ Indonesia	2	50	25

Main Research Topic

This study used VOSviewer software to generate A list of keywords that appeared at least twice in all the publications related to STEAM-ES. Each circle shows a keyword, and the circle size reflects how frequently the keyword occurs. Relationships between circle mean relatedness or co-occurrence in relevant studies, with closely related keywords depicted in the same colour. Additionally, related keywords are given a similar colour.

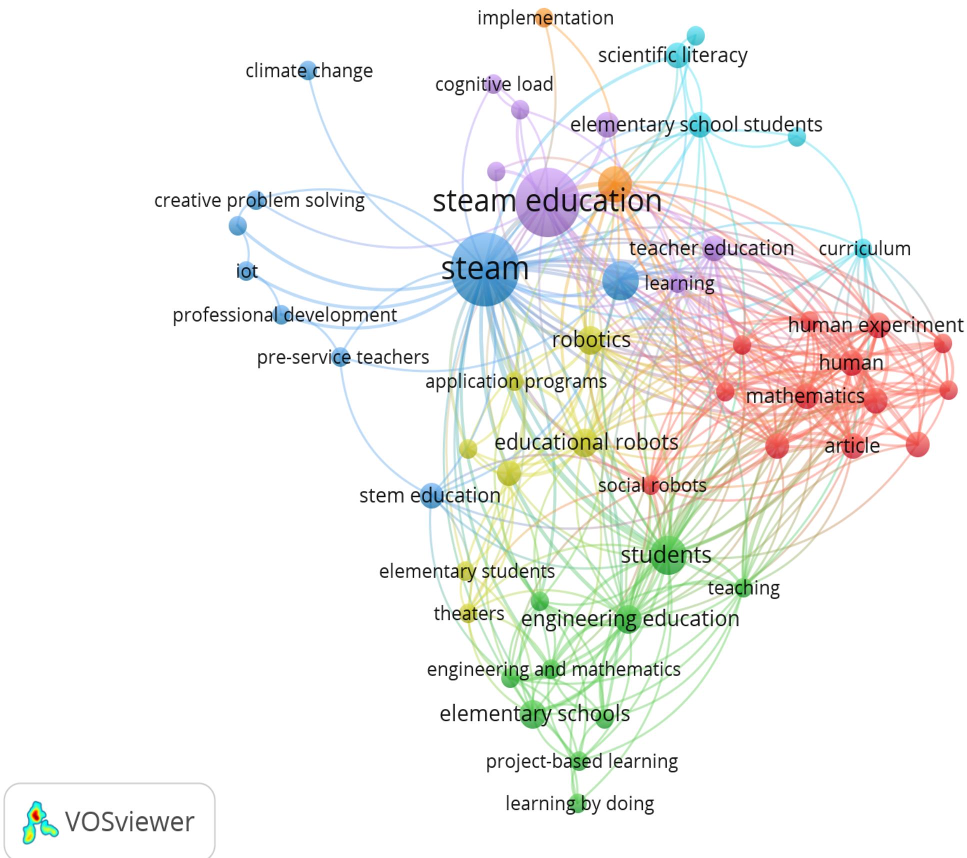

Figure 4. Network Exploration of 53 Keywords in STEAM-ES

The most occurring keywords were analyzed first before mapping the keywords in publications on STEAM-ES during 2015-2024, as shown in table 5. It can be seen that the highest total link strength (84) and the most frequently occurring keyword (25) is "STEAM".

Table 5. Most occurrence keyword of STEAM-ES Publication

Keywords	Occurences	Total Link Strength
Steam	25	84
Steam Education	22	36
Elementary School	7	21
Students	7	59
Elementary Education	6	33
Educational Robots	4	35
Elementary Schools	4	16
Engineering Education	4	36
Robotics	4	34

Metadata keywords were mapped to identify recommendations for publications on STEAM-ES. To find novelties for future research, keywords were broken down from the most to the least significant links.

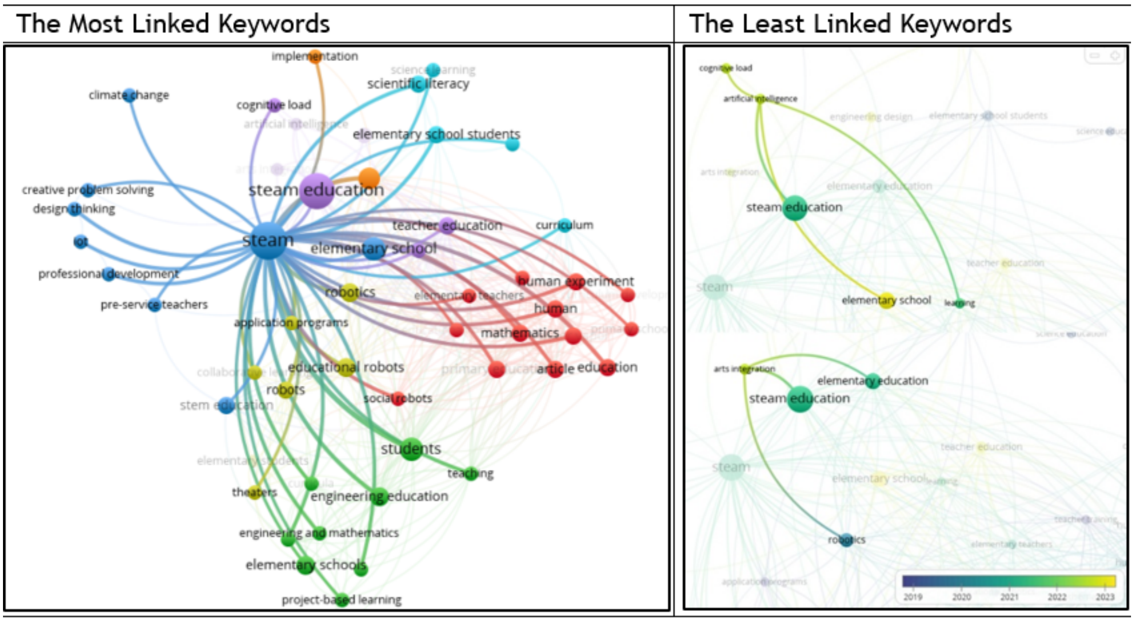

Figure 5. The Most and The Least Linked Keyword

From the results of Vosviewer mapping on keywords with the most links ('STEAM'), we can identify topics that have been researched in the last 10 years. However, among the many interrelated topics above, there are several topics that are still minimal and highly recommended for future research. The recommended mapping of research topics on STEAM-ES can be seen right-above figure.

The research recommendations in the field of STEAM-ES as we visualize from the least linked keywords, the main keyword 'steam education' with 'elementary school' has connection on several keywords like 'learning'; 'artificial intellegence'; and 'cognitive load'. Meanwhile, we also can find interconnection between various keywords such as 'steam education'; 'elementary education'; 'robotic'; and 'arts integration'. Both keywords combination can open up new research opportunities on future.

Most Influential Documents

Table 6 describe a brief review of the ten most influential publications from a total of 68 documents sorted by most citations. The review includes the context associated with STEAM; the approach used; the instruments used; the problems encountered; the research findings; and the recommendations.

Among the ten articles, The most-cited article was a study on design thinking in STEAM-ES by the collaborative authors Cook, K. and Bush, S (99 citations).

Table 6. Ten Most-Cited Articles

CR	Title	TC	STEAM Related Context	Researh Method
1	Design thinking in integrated STEAM learning: Surveying the landscape and exploring exemplars in elementary grades (26)	99	Design Thinking (DT)	Case study
2	Co-Measure: developing an assessment for student collaboration in STEAM activities (27)	83	Collaborative Problem Solving (CPS)	Research And Development
3	Analysis of Korean Elementary Pre-Service Teachers' Changing Attitudes About Integrated STEAM Pedagogy Through Developing Lesson Plans (28)	80	Responses and attitudes of prospective primary education teachers	Mixed-method
4	The exploration of continuous learning intention in STEAM education through attitude, motivation, and cognitive load (29)	74	Student attitudes, motivation, and cognitive load	Eksperimental
5	Project-based learning oriented STEAM: the case of micro-bit paper-cutting lamp (30)	45	Student creativity	Experimental
6	STEAM Designed and Enacted: Understanding the Process of Design and Implementation of STEAM Curriculum in an Elementary School (31)	44	Inquiry problem solving learning design	Qualitative
7	The effects of STEAM-based mobile learning on learning achievement and cognitive load (32)	43	Student learning outcomes and cognitive load	Experimental
8	Steam-project-based learning integration to improve elementary school students' scientific literacy on alternative energy learning (33)	42	Science literacy	Qualitative
9	Fostering AI Literacy in Elementary Science, Technology, Engineering, Art, and Mathematics (STEAM) Education in the Age of Generative AI (34)	40	AI (Artificial Intelligence) literacy	Research And Development
10	Social steam learning at an early age with robotic platforms: A case study in four schools in Spain (35)	38	Educational robotic technology	Mixed-method

STEAM Related Context

The top ten most-cited article identified several STEAM contexts, categorized as: student, teacher, learning design, and learning support media. The student contexts most often associated with STEAM are: science literacy, learning outcomes, cognitive load, learning experiences, and AI literacy.[26,27,28,29,30,31,32,34,36]

This aligns with the characteristics of STEAM as a form of Student-Centered Learning that promotes interdisciplinary learning, active participation, and the development of essential skills, preparing students to effectively address 21st-century challenges.[37,38,39]

The context of STEAM teachers and STEAM instructional design in the next section is important. Teachers' responses to STEAM learning and the development of STEAM instructional design [28,31] are crucial factors in improving educational quality. Well-designed instructional materials and effective teaching practices result in student engagement and better learning outcomes.[40,41]

Lastly, the context often associated with STEAM includes supporting media such as robotics and digital media.[32,35]

In this context, learning media play a significant role in achieving educational objectives at the primary education level by improving students' interest and motivation to learn,[42] integrated with technological innovations,[43] and accommodating students' diverse learning styles.[44]

Learning Approach

In addition to several contexts associated with STEAM, our search also revealed several approaches used to implement STEAM learning, including: Project-Based Learning; Game-Based Learning; Classroom Action Research; and Design Thinking.

Project-based learning is the most widely used approach in STEAM learning. Combining PBL with STEAM helps students develop in a well-rounded way by combining hands-on learning with knowledge from different subjects;[45,46] In addition, game-based learning and classroom action research can be alternative approaches to be applied in STEAM learning. Games make learning fun and interactive, which motivates students. This approach can help you develop different skills, like art, science, and math, by doing fun activities.[47] Classroom

Action Research helps teachers improve their teaching methods and get students more involved in class. This method has been shown to improve how well teachers are at teaching and how professional they are. It makes them more effective at teaching STEAM.[48]

Challenges Faced and Solutions

STEAM learning implementation often faces challenges. Our analysis has identified four categories: student, teacher, resource, and infrastructure challenges. Students have difficulty understanding theoretical concepts in AI-based STEAM learning. These challenges can be mitigated by providing guidance.[34] Another challenge is the assessment rubric for co-measure instruments; the language needs to be adjusted.[27] Students also struggle with creating designs for STEAM micro-bit paper-cutting lamps. Therefore, teachers need to provide more demonstrations and use physical objects.[30]

Teachers face challenges like time management and developing learning project designs.[36] This problem can be solved by providing regular feedback on designing STEAM lesson plans.[28] Prospective teachers also have trouble combining learning materials with science, obtaining science activities, and aligning STEAM-based lesson plans. They require guidance to ensure all topics are aligned with learning objectives. Examples of integrated STEAM learning designs are recommended.[28] Teachers with no technical background struggle with robotics-based STEAM learning, so mentoring by relevant academic backgrounds is necessary.[35]

Other challenges identified from primary education content/learning resources include limited availability of varied STEAM resources,[36] which are integrated with digital technology.[29]

Development research in collaboration with practitioners will produce the latest STEAM learning resources needed.[21] Some STEAM designs are irrelevant to current curriculum, highlighting the need for specific support strategies for teachers.[31] Infrastructural challenges include device availability and quality. Selection of suitable devices is crucial.[32]

Findings and Future Works

In accordance with the review summary in table 7, the findings and recommendations for future research are outlined as follows:

1. STEAM-PjBL integration helps students see how science knowledge can be applied to everyday life. It also encourages curiosity, problem-solving, creativity, and collaboration. This research also gives teachers a chance to learn how to use different learning models. Future studies should extend the teaching period and evaluate the long-term impact of PBL STEAM on students' learning attitudes.[30,36] Researchers and educators should use the Co-Measure rubric to evaluate how well students work together to solve problems.[27]
2. STEAM combined with game-based learning can improve student learning. The material may be expanded to include other units or subjects.[32]
3. STEAM learning combined with AI supports grade 5 students in understanding AI principles, emphasizing creativity and ethics. Future research could include various students and study improvements in AI literacy.[34] A combined AI-based STEAM education game has a positive effect on students' learning intentions and enhances the connection between learning attitudes and intentions. Cognitive load negatively impacts perceived usability. Future studies should collect samples from different cultures for a comparative study.[29]
4. A STEAM workshop for future elementary teachers showed several findings. Designing STEAM lessons made participants more aware of and appreciate STEAM. Teacher-given STEAM combined with a problem-based learning workshop led to better problem design and instructional pathways aligned to the STEAM model, with more inquiry and authentic tasks. Next steps include creating support structures and providing materials.[31] STEAM and design thinking should be used to teach elementary students integrated science and math. The empathy phase of the DT framework motivates students to solve problems.[26] Another workshop worth trying is robotic STEAM learning. The training received a positive response, and teachers found it useful. Teachers with more initial interest and lower programming skills performed better in the training. Teachers with these skills would also benefit from more support. We also recommend improving the initial student evaluation by adding more assessment points and tools, such as interviews and video recordings.[35]

DISCUSSIONS

The study examined global research trends related to STEAM learning in primary education over the past decade by analyzing Scopus data using bibliometric methods. Although the first research in this field appeared on Scopus in 2015, Over the past decade, The count of publications from case studies has grown significantly. Our finding showed that the period from 2019 to 2020 saw the most significant growth of publications and citations (figure 2). Other studies have also found the same thing, which there is an fluctuating increase in

STEAM publications during the period 2017-2021.[25] During that period, STEAM transformed from the traditional STEM (Science, Technology, Engineering, Mathematics) approach, which focuses on convergent skills, to a popular pedagogical approach that focuses on divergent skills, as found in art degrees.[49] It equips individuals with a variety of skills essential for economic growth.[50]

The USA has more publications and citations than other countries (table 2). Previous research has also shown that the USA dominates research and development in visionary educational approaches such as STEAM.[25] This indicates that it is the most reputable source for information on this topic. The USA is the leading country in this field, as shown by the fact that many of the most cited authors, institutions, and scientific articles in this field come from the USA. Institutions from the United States are the most active in collaborating with countries like Indonesia, South Korea, and China (figure 4). Daniel Herro is the most productive STEAM elementary education author (see Bibliography). Table 4 shows that more top STEAM-ES scientific journals are in the Scopus Q4. 'The Frontiers in Education journal' has three publications and is ranked 62nd in education. 'The International Journal of STEM Education' is the most cited journal with 157 citations, ranked 98th in education.

Our database analysis shows that the most impactful STEAM articles focus on student contexts and challenges when implementing STEAM. In line with these findings, other studies have also found that STEAM research often focuses on developing critical and creative skills in students.[49] The result aligning with its role in student-centered learning, promoting interdisciplinary learning, active participation, and preparing students to address 21st-century challenges.[37] Project-based learning is the most common approach in STEAM education. Combining PBL with STEAM lets students learn by doing and applying what they're learning in different subjects.[45]

Future studies suggested from analized study recommending to extend the teaching period and evaluate the long-term impact.[17] It's also crucial to consider curriculum alignment with lesson plans and teaching practice with policy and materials. Teacher educators and researchers play a role in the process.[28] We also suggest supporting teachers with less ability and greater interest. Furthermore, Adding assessment points and tools like interviews and video recordings can improve the initial study evaluation.[35] Another bibliometric study suggests that policy decisions should focus on supporting locally-based research projects and the advancement of culturally-relevant STEAM educational programs.[25]

CONSCLUSION

Over the past decade, the count of publications from case studies has grown significantly. Our finding showed that the period from 2019 to 2020 saw the most significant growth of publications and citations. USA has a higher number of publications and citations than the bibliography average. This is demonstrated by the USA consistently being the country of origin of the most cited authors, institutions, and scientific articles in this field of study. USA also proved to be the most active Country in collaborating with another countries from Asia. Meanwhile, top scientific journals that contribute to this field of study are found more in Scopus Quartile 4.

STEAM is most often associated with improving students' skills. Project-based learning is its most widely used approach, but challenges do exist, particularly around understanding theoretical concepts and technical complexities in AI-based STEAM learning. Research is needed on integrating AI-based STEAM into elementary education, as well as on integrating art aspects into robotics-based STEAM learning. Future studies should extend teaching periods to evaluate the long-term impact of PBL STEAM and collect samples from different cultures, while curriculum alignment with lesson plans and teaching practice is crucial.

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