ANALYZE OF STEAM EDUCATION RESEARCH FOR THREE DECADES

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Abstract

The main objective of research is to ascertain the existing situation of STEAM education research over three decades based on the Scopus database. The entire documents are 256 findings globally data shorted by year, region, and highest cited to 100 documents. The analysis technique used VOSViewer, Microsoft Excel and word cloud generator. The result of document type articel is ranks first in Global and conference paper rank first in South East Asia. The sources that have published the top cited papers are "Journal of Small Business Management" in global and the "Education Sciences" in South East Asia. Meanwhile, the author with the most citations is Jeon M from the U.S.A. Specifically, the country with the most publications is US with 31 articles and 2553 citations. Whereas the majority of Southeast Asian countries have 9 articles and 10 citations. Supported the visualization analysis, VOSViewer's global region is divided into 4 clusters and 62 keywords to assist with the visualization analysis. A pair of clusters containing 14 keywords each for the South Asia region. The terms program, project, environment, model, and implication are frequently used in STEAM throughout the world. The keyword STEAM education appears in analyses conducted in South-East Asia. The outcome of this research can serve as a resource for scholars interested in STEAM and education. Further research into STEAM education trends can be conducted by focusing on a single region or on more specific issues.

Keywords – Bibliometric, Education, STEAM, STEM, VOSViewer.

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1. Introduction

Globally, society has become increasingly reliant on technology, developing into digital citizens. Intelligent devices are now pervasive in our world, which is enormously impacted by technology (Bedar & Al-Shboul, 2020). On the other hand, educational practices flourish when students' attention has been obtained. Developing an uplifting learning environment appears to be a complex process. Educators and policymakers are constantly confronted with new frameworks focused on improving motivation and fostering an optimal learning environment. Science, Technology, Engineering, and Mathematics (STEM) are domains that provided a significant impact on global progress, innovation, and the potential for resolving the world's most pressing issues (Poverty, renewable energy, and environmental damage)

(Wajngurt & Sloan, 2019) STEM enhanced students should not literally memorize concepts; they comprehend the idea of science and its relationship to daily life. STEM applications foster meaningful learning by encouraging students to construct, establish, and engaged (Fiteriani, Diani, Hamidah & Anwar, 2021).

Correspondingly, it is frequently stated that school-level knowledge of mathematics, engineering, and natural sciences is inadequate. As a result, it became crucial to incorporate creative pillars into STEM education, titled "Arts," in order to enrich this field with innovative components (Anisimova, Sabirova & Shatunova, 2020a). Under a proper overview of what creative is and its socioeconomic implications throughout the 21st century, learner mentorship and education needs transform. Promoting motivation and inventiveness is a potential approach. Positive outcomes have already been stated in the stage of growth of STEM to STEAM (Conradty & Bogner, 2018). STEAM is a reimagining of the STEM approach by incorporating an element of art. Essentially the same principle applies to fostering creative ideas. (Moon & Kang, 2015). The distinction is in the area of art and design, which allows learners to immerse into their potential than was previously available with previous ones. STEAM provides the opportunity to develop and connect ideas between art, music, and science (Anindya & Wusqo, 2020). STEAM education becomes established globally than STEM education because it may be merged into another multidisciplinary topic, such as the environment (Suganda, Latifah, Irwandani, Sari, Rahmayanti, Ichsan et al., 2021). In practice, STEAM is often associated with constructivist learning models such as Project-Based Learning (PjBL), Problem Based Learning (PBL) and Inquiry Learning (Badriyah, Anekawati & Azizah, 2020; Mufida, Sigit & Ristanto, 2020; Budiyono, Husna & Wildani, 2020; Salmi, Thuneberg & Bogner, 2020). Learning using STEAM approaches can train 21st century skills (Rahmawati, Agustin, Ridwan, Erdawati, Darwis & Rafiuddin, 2019) such as problem solving (Anindya & Wusqo, 2020), creative thinking (Putri, Rusdiana & Suwarma, 2019; Suganda et al., 2021), building students' soft skills (Widarwati, Utaminingsih & Murtono, 2021), science process skills (Suryaningsih, Fakhira & Nisa, 2021), and critical thinking (Diana & Saputri, 2021).

Bibliometric study utilizes descriptive statistical analysis to chart the transformation of research within the scope of a particular topic (Hallinger & Kovačević, 2019). Research on bibliometric analysis in STEAM education topics has been conducted by several researchers (Kwak & Ryu, 2016). The bibliometric analysis using VOSviewer is a genuine advancement despite the existence of prior research. The study examined research achievement over four years and suggested a guiding light to determine the direction of STEAM educational research. The number of STEAM education papers continued to increase from 2011 to 2014 but the increase in research tended to stall in 2014 (Chomphuphra, Chaipidech & Yuenyong, 2019). The quantity of academic submissions was seen to have expanded substantially throughout the decades. Furthermore, we discovered that the United States was among the leading countries that contributed STEAM publications across the decades. STEAM learning research began in 2006 and shows that STEAM has not had a well-proposed and robust path of studies throughout period, however dynamics in this area tend to favor the scientific branch of education (Marín-Marín, Moreno-Guerrero, Dúo-Terrón & López-Belmonte, 2021).

An outline of past studies has been presented STEAM Education research. Some of these papers have examined the state-of-the-art of biblical research. Marín-Marín et al. (2021) uses co-word analysis to describe keywords and citation results within the scope of STEAM educational research. Web of Science (WoS) databases are used in the process of retrieving data. The WoS program analyzed results, citation reports and SciMAT was used, as many as 1116 manuscripts were analyzed. (Syahmani, Hafizah, Sauqina, Adnan & Ibrahim, 2021) used Publish or Perish software to search for articles that fit the Google Scholar database. The use of mind-mapping methods that emphasize the limitations of research with environmental literacy as a research center. A vast number of topics are covered in STEAM studies, namely the environment (Santi et al., 2021; Suganda et al., 2021; Syahmani et al., 2021), chemistry (Rahmawati et al., 2019), physics (Moon & Kang, 2015; Ozkan & Umdu-Topsakal, 2021), augmented reality (Jesionkowska, Wild & Deval, 2020), computation (Bati, Yetişir, Çalişkan, Gunes & Saçan., 2018; Gomoll, Hmelo-Silver, Šabanović & Francisco., 2016; Vicente, Mena, Mínguez & González, 2021).

The primary goal of this research is to use bibliographic analysis to investigate the existing situation of STEAM education research. Data collected from the Scopus database during a three-decade period. This study was used to address the underlying issues:

1. How is the pattern of publication on STEAM Education topic in South East Asia over the three decades, based on the keyword, types and source?
2. Who are the top author and affiliation for STEAM Education research?
3. Which country that has most interested in STEAM research, based on the collaboration?
4. How do South East Asia researchers contribute to STEAM Education research for the last three decades?
5. How is the visualization of research trends in STEAM Education for the last three decades?
6. What are the differences and similarities between STEM and STEAM?
7. What are the advantages and disadvantages between STEM and STEAM?

2. Theoretical Analysis

2.1. Changeover from STEM to STEAM

STEM education has undergone a significant pedagogic revolution, resulting in a variety of educational experiences. Although it has the same educational philosophy in theory, significant variances have emerged in practice. STEM is concentrated on problem solving using concepts and procedures from science and mathematics, as well as engineering tactics and the application of technology (Aguilera & Ortiz-Revilla, 2021). Dynamic and competitive conditions necessitate divergent thinkers with both adaptable and unique cognition and the capacity to develop a plethora of concepts and thorough remark on broaden and elevate existing concepts (Hunter-Doniger & Sydow, 2016). While further, in the academic context, students should develop their ability to think creatively, as this is a crucial skill for career advancement (Oner, Nite, Capraro & Capraro, 2016). STEAM expanded STEM by including the "Art" design ideas. STEM or STEAM are both transdisciplinary processes that employ a project-based approach (Watson, 2020). STEAM initiative revealed an emerging notion that STEM disciplines should be prioritized in Educational alone will not suffice to suit the learners' needs. Science, technology, engineering, and mathematics education. Additionally, expect the arts to be a focal point of learning. (Reinholz & Andrews, 2020; Rolling, 2016). STEAM would cultivate a multidimensional zone which cannot be characterized in terms of any traditional form of discrete disciplines, including the cavity formed whenever learners refrain from categorizing their learning as science, technology, or art. (Lin & Tsai, 2021).

Several researches had been found that STEAM could help fostering creativity and new ways of thinking. (Radziwill, Benton & Moellers, 2015) found that in comparison with STEM-only he recognized that project centered with STEAM could enhance learner's perspective to work creatively. STEAM field can be brought to solve problems, design system, and live a more earth-friendly lifestyle (Teasdale, Ryker, Viskupic, Czajka & Manduca, 2020). The advantages of STEAM education varied from, developing learners' self-directed learning potential, cultivating the appropriate character, and enhancing students' academic outcomes (Lee, 2021). STEAM education strengthened learners' theoretical comprehension and diminished their reliance on misconceptions. (Ozkan & Umdu-Topsakal, 2021).

2.2. STEAM in Educational Practice

The process of learning seems focused around what students would be doing as individuals that engage to knowledge construction, whereas the teaching process is directed around where teachers are doing as facilitators of learning. Both parts will occur concurrently and will be integrated into an activity during the interaction between students and teachers, including between learners throughout the educational process (Widarwati et al., 2021). Increased knowledge, abilities, and attitudes are formed by teaching methods that are contemporary, and these methods can boost skill, enthusiasm, and willingness to innovate through the expression of theoretical and practical creative ideas (Sudana-Degeng, Sutadji, Rinanityas, Prihatin, Priawasana & Mais, 2021). STEAM engages students in transformative learning,

which is based on Five distinct modes of knowledge are closely linked: sociocultural knowledge, interpersonal knowledge, critical knowledge, inventive and ethical knowledge, and knowledge in action (Kang, 2019). STEAM is one of several learning strategies which can be used to enhance student' learning results on both cognitive and affective levels, mainly in the field of science (Triwahyuni, Kadek-Suartama, Aswit & Barata, 2021). STEAM is a pedagogical model that combines science, technology, engineering, art, and mathematics.

STEAM learning encourages independence for students in favor of transforming the classroom into a learning community. Motivated by the interdisciplinary of science and engineering. The primary goal of the science education process is to stifle learners' enthusiasm. and to encourage them to engage involved in learning so that their curiosity can be satisfied through their own explorations (Jho, Hong & Song, 2016). Integrated STEM or STEAM education necessitates a shift in teacher pedagogies to incorporate real-world problem solving or design-based techniques (MacDonald, Hunter, Wise & Fraser, 2019). It is critical for STEAM education that teachers collaborate with their colleagues and produce their own multidisciplinary (open-ended and innovative) procedures. In this spirit, it is critical to establish an educator from diverse disciplines, to build good communication channels between them, and to deal with problems that emerge during the STEAM education process (Jho et al., 2016). Since 2011, Chicago has backed the project "Scientist for the Future". This project initiatives a collaboration of universities, after-school programs, and practitioners of no-classroom education to implement a STEAM-based training course. Throughout the academic period, the program is organized over all communities and Diverse educational modules are offered, including "Sustainable fuels," "Sound physics and music mathematics," "Human and nature," and "Robotic systems." Moreover, "Astrophysics" was learned during periods of time not occupied by fundamental studies or work (Anisimova, Sabirova & Shatunova, 2020b).

3. Methodology

This research used descriptive statistical analysis based on bibliometric analysis to trace the transformation of research in the field of STEAM (Science, Technology, Engineering, Art, and Mathematics) education (Kulakli & Osmanaj, 2020; Yang, Huang, Sun & Zhang, 2017). The shift from STEM to STEAM research in education was documented thirty years ago by Scopus metadata on the keywords "STEAM" and "Science Education." Flow research bibliometric based as 1.) Search keyword. 2.) Filter an article. 3.) Refinement of search results. 4.) Extracting search results in VOSViewer Software. 5.) Data Analysis (Hudha, 2020).
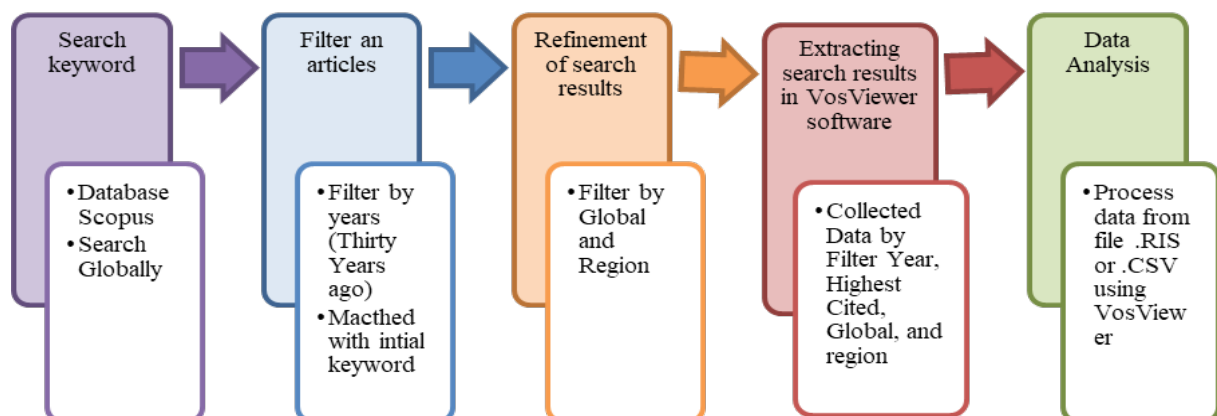

Figure 1. Five steps of focused bibliometric analysis

3.1. Search Keyword

STEAM and Education Sciences are the main focus of this study. This study's primary database was built with metadata culled from Scopus. Shorted by year and citations to the 100 most often cited sources, the total number of findings is 256.

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255 document results
TITLE ( steam AND education ) AND ( LIMIT-TO ( PUBYEAR , 2022 ) OR LIMIT-TO ( PUBYEAR , 2021 ) OR
LIMIT-TO ( PUBYEAR , 2020 ) OR LIMIT-TO ( PUBYEAR , 2019 ) OR LIMIT-TO ( PUBYEAR , 2018 ) OR LIMIT-TO
( PUBYEAR , 2017 ) OR LIMIT-TO ( PUBYEAR , 2016 ) OR LIMIT-TO ( PUBYEAR , 2015 ) OR LIMIT-TO (
PUBYEAR , 2014 ) OR LIMIT-TO ( PUBYEAR , 2013 ) OR LIMIT-TO ( PUBYEAR , 2012 ) OR LIMIT-TO (
PUBYEAR , 2011 ) OR LIMIT-TO ( PUBYEAR , 2009 ) OR LIMIT-TO ( PUBYEAR , 2006 ) OR LIMIT-TO (
PUBYEAR , 1997 ) OR LIMIT-TO ( PUBYEAR , 1967 ) )
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Figure 2. Initial search

3.2. Filter an Articles

The search turned up massive amounts of document spanning the years 1992 to 2022. concentrated on journals that contained the keywords used in the original search.

3.3. Refinement of Search Results

Papers sorted by year and greatest citation count will be filtered by geography, namely the world and Southeast Asia, reducing the number of documents from 100 to 26.

3.4. Extracting the Results in VOSViewer Software

The data was extracted from RIS with supporting components, namely the type of article, the year, the region, and the most prevalent source, and resulted in the identification of 100 documents meeting the highest citation criteria and 26 documents meeting the global and regional citation criteria.

3.5. Data Analysis

The data from search results as shown in Figure 3.

```
TITLE ( steam AND education ) AND ( LIMIT-TO ( PUBYEAR , 2022 ) OR LIMIT-TO ( PUBYEAR , 2021 ) OR
LIMIT-TO ( PUBYEAR , 2020 ) OR LIMIT-TO ( PUBYEAR , 2019 ) OR LIMIT-TO ( PUBYEAR , 2018 ) OR LIMIT-TO
( PUBYEAR , 2017 ) OR LIMIT-TO ( PUBYEAR , 2016 ) OR LIMIT-TO ( PUBYEAR , 2015 ) OR LIMIT-TO (
PUBYEAR , 2014 ) OR LIMIT-TO ( PUBYEAR , 2013 ) OR LIMIT-TO ( PUBYEAR , 2012 ) OR LIMIT-TO (
PUBYEAR , 2011 ) OR LIMIT-TO ( PUBYEAR , 2009 ) OR LIMIT-TO ( PUBYEAR , 2006 ) OR LIMIT-TO (
PUBYEAR , 1997 ) OR LIMIT-TO ( PUBYEAR , 1967 ) ) AND ( LIMIT-TO ( AFFILCOUNTRY , "Thailand" ) OR
LIMIT-TO ( AFFILCOUNTRY , "Indonesia" ) OR LIMIT-TO ( AFFILCOUNTRY , "Malaysia" ) OR LIMIT-TO (
AFFILCOUNTRY , "Philippines" ) OR LIMIT-TO ( AFFILCOUNTRY , "Singapore" ) )
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Figure 3. Shorten data analysis by region South Asia

Analyzed datasets will be produced based on the most cited data. .RIS or CSV files with the results of the analysis will be made available for download. Using VOSViewer, we saw how the.RIS file metadata keywords are connected to each other in a network diagram (Matulaitienė, 2021). Descriptive analysis is a second analytical technique that examines data such as year and country of publication as well as the affiliation and language of those analyzed. Microsoft Excel and a word cloud generator can be used to visualize CSV metadata.

4. Result and Discussion

4.1. Document Type

Document Type	Global				South East Asia			
	F	Total Cited	Mean	Median	f	Total Cited	Mean	Median
Article	59	1029	17.44	5	12	37	3,083	3
Conference Paper	37	369	9.95	6	13	17	1,307	2
Editorial	2	39	19.5	19.5	1	0	0	0
Review	2	29	14.5	14.5	–	–	–	–

Table 1. Document type of top cited STEAM research

Table 1 show in Global, STEAM research in global have 59 articles with mean 17.44 and median 5, 37 Conference paper with mean 9.95 and median 6, 2 editorials with mean and median 19.5, and 2 Review with mean and median 14.5. The document type of top cited in global is article. In South East Asia, STEAM research has 12 articles mean 3.083 and median 3, 13 conference papers with mean 1.307 and mean 2, and 1 editorial papers. The total citation rate of article is the highest number. The most language used in each the top one hundred cited papers over the last thirty years has been English.

4.2. Source Publishing

There are so many sources either journal or conference paper have published the top cited papers about STEAM. In global, the "Journal of Small Business Management" that have published the top cited papers were 278 ACPP (average citations per papers) with total 278 citations. On other hand, the "Education Sciences" that have published the top cited papers on STEAM were 1 paper with 21 citations.

Global				South East Asia			
Source Title	TC	TP	ACPP	Source Title	TC	TP	ACPP
Journal of Small Business Management	278	1	278	Education Sciences	21	1	21
Eurasia Journal of Mathematics, Science and Technology Education	104	6	17.33	IOP Conference Series: Materials Science and Engineering	8	1	8
Computer	81	1	81	Universal Journal of Educational Research	7	2	3.5
Art Education	67	1	67	Asian Journal of University Education	4	1	4
Procedia Computer Science	67	1	67	2016 IEEE International Conference on Real-Time Computing and Robotics, RCAR 2016	2	1	2
Journal of Engineering Education	60	1	60	AIP Conference Proceedings	2	1	2
Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)	77	5	15.4	International Journal of Design Education	2	1	2
Education Sciences	56	5	11.2	International Journal of Mathematical Education in Science and Technology	2	1	2
Communications in Computer and Information Science	50	1	50	Journal of Physics: Conference Series	2	6	0.3
Journal of Educational Change	43	1	43	Proceedings of 2018 IEEE International Conference on Teaching, Assessment, and Learning for Engineering, TALE 2018	2	1	2

TC: total citation; TP: total paper; ACPP: average citation per paper

Table 2. Source publishing STEAM research

4.3. Top Authors

Table 3 describes the top authors, the number of most cited papers, author's region and the affiliation of STEAM research. There are top authors who have published two or more of the top cited papers. Jeon M. from United States are the top global author that have published many papers about STEAM research and the highest link strength (39). Piperopoulus's paper from United Kingdom has published 1 paper and the highest total citation paper. Besides, Ishartono from Indonesia is the top South East Asia author that have published many papers about STEAM research and the highest link strength (4). Therefore, from received the greatest number of paper citations about STEAM research.

In South East Asia, there are three clusters and Ishartono's cluster are the biggest author clusters that have top cited papers. Therefore, in global, there are five cluster and Jeon, M. is the biggest clusters that have top cited Link strength in global.

Global						South East Asia					
Author	TP	TC	LS	Region	Affiliation	Author	TP	TC	LS	Region	Affiliation
Jeon M	2	19	39*	United States	Michigan Tech	Ishartono	3	0	4	Indonesia	Muhammadiyah Surakarta University
Barnes J	5	21	34			Prayitno	2	0	4		
Karageorgiou Z.	2	7	4	Greece	Hellenic Open University	Sutama	2	0	4		
Kim B. H	2	15	2	South Korea	Korea National University of Education	Akatimagool	2	1	2	Thailand	King Mongkut's University of Technoogy North Bangkok
Piperopoulos P.	1	278*	1	Unuted Kingdom	University of Bath	Ruangsiri	2	1	2		
Park N.	4	28	0	South Korea	Newcastle University	Morales	3	7	0	Philiphine	Philippine Normal University

TP=total papers, TC=total citation, LS=link strength*the highest number

Table 3. Top author of top cited paper in global and South East Asia

4.4. Year Wise Distribution

The top cited papers of STEAM research have been published for the last thirty decades, which 2018 is the year with highest number in South East Asia (11) area and (20) in global. Thus 2019 with 5 papers was the largest published year in South East Asia and 2018 with 20 paper was the largest published year in Global. STEAM research in South East Asia has mean citations per paper was the highest at 6,6 in 2019 and the mean citations per paper per year was the highest at 2,2 in 2019. In addition, in Global, the mean citations per paper was the highest at 29,82 in 2016 and the mean citations per paper per year was the highest at 9,6 in 2015.

Year	Global				Citable Years	South East Asia			
	Papers	TC	ACPP	ACPPY		Papers	TC	ACPP	ACPPY
2012	4	103	25.75	2.575	10	–	–	–	–
2013	6	178	29.67	3.296	9	–	–	–	–
2014	3	25	8.33	1.042	8	–	–	–	–
2015	5	336	67.2	9.6*	7	–	–	–	–
2016	11	328	29.82*	4.97	6	1	2	2	0.33
2017	7	68	9.71	1.94	5	–	–	–	–
2018	20*	192*	9.6	2.4	4	11*	3	0.27	0,06
2019	14	91	6.5	2.16	3	5	33*	6.6*	2.2*
2020	17	85	5.0	2.5	2	8	5	0.62	0.31
2021	11	42	3.82	3.81	1	9	3	0.33	0.33

TC: total citation; ACPP: average citations per paper; ACPPY: average citations per paper per year; *the highest number

Table 4. Year wise distribution of top cited papers

4.5. Country or Region

The Scopus database were then sorted by author affiliation and country. Only the first author was considered when calculating the country of publication. There are countries was contributed in STEAM research in global such as United States (31 paper), South Korea (23 paper), Lithuania (6 paper), Australia and Taiwan each (4 paper). Besides, South East Asia have countries that productive published STEAM papers. Thailand (9 paper), Indonesia (9 paper), Philippine (3 paper), Malaysia (2 paper), and Singapore (1 paper. The United States is the most productive country in global STEAM research, having published 31 publications that have been cited 2553 times. Meanwhile In South East Asia, Thailand has published 9 papers with a total of 10 citations.

Global			South East Asia		
Country	Papers	Citations	Country	Papers	Citations
United States	31*	2553*	Thailand	9*	10*
South Korea	23	344	Indonesia	9	10
Lithuania	6	27	Philippine	3	7
Australia	4	29	Malaysia	2	6
Taiwan	4	15	Singapore	1	21*

*The highest number

Table 5. The country of top cited papers

4.6. Keyword

The most frequently used keywords are indicated in Figure 4. The font size image indicates that the words are often used in this paper. The words used more frequently in global are STEAM, educations, students, STEM, curricula etc. While South East Asia are STEAM, students, study, teaching etc. In support of this statement, immersive STEAM-VR education has emerged as a novel technological application in recent days that has the potential to boost students' enthusiasm and interest in learning (Hsiao & Su, 2021). Despite the growth and integration of STEAM programs in science, there has been little consideration of the conceptual frameworks that could serve as solid recommendations for scientific educators and instructors when creating and delivering STEAM curricula (Chu, Martin & Park, 2019). The preponderance of STEAM studies has been on curricular formation and pedagogy, with a focus on emerging 21st-century skills (Upadhyay, Coffino, Alberts & Rummel, 2021). Creativity is a crucial skill for the 21st century; this teaching and learning process should be incorporated throughout all instruction, with meaningful and relevant learning activities that foster student initiative and responsibility, particularly curriculum design (Madden, Baxter, Beauchamp, Bouchard, Habermas, Huff et al., 2013). Due to the eagerness of instructors and learners to share their work, linkages across all sorts of makers foster community building through the production, presentation, critical examination, and discussion of process innovations (Patton & Knochel, 2017).

Figure 4. The keywords of STEAM research

Global				South East Asia			
Term	Occurrences	Relevance	LS	Term	Occurrences	Relevance	LS
Variety	5	2.83	35	Teaching	6	1.47	35
Child	10	2.17	64	Activity	9	1.35	48
Addition	7	2.05	34	Problem	8	1.25	55
Term	7	1.93	39	Sample	5	1.22	30
Communication	6	1.80	2134	Mathematics	17	1.03	102
Math	7	1.78	41	Science	15	0.98	94
Computational Thinking	5	1.71	30	Arts	13	0.95	83
Robot	13	1.70	105	Steam education	19	0.91	99
Lack	7	1.68	2134	Students	17	0.86	99
Korea	10	1.57	67	Assessment	6	0.85	34

LS: link strength

Table 6. The top 10 term of top cited papers

According Table 6, STEAM education has similar term, mathematics, get highest link strength in South East Asia. Besides, the "communication" and "lack" get highest link strength in 2134 for STEAM research in global. Based on the previous research conducted by (Nopiyanti, Adjie & Putri, 2020), STEAM education become more effective when combined with project-based learning. PjBL is a teaching technique that focuses on students undertaking constructive inquiries of open questions in communities and integrating their skills to build authentic products that facilitate cooperation, communication, and evaluation. STEAM and PjBL together have the power to stimulate all facets of childhood development comprehensively, including communication skills. Nevertheless, an intriguing perspective emerged from (Ho, La, Nguyen, Pham, Vuong, Vuong et al., 2020). While efforts to support STEAM education have increased over the years, it continues to be plagued by prejudices that are ingrained in the nation's culture and the way we were reared. STEAM education has the potential to alter students' thinking they become more involved in activities that make a significant contribution in living.

Unfortunately, STEAM education has been mostly inactive at the school level considering the lack of knowledge of STEAM education, an inadequate educational program, and administrative issues (Kim & Lee, 2018). Additionally, China has contributed to the establishment of STEAM education by forming a favorable governmental environment and actually encouraging educational reform. However, due to China's education system's delayed transformation, the STEAM education cognitive idea wasn't standard, the setup is unequal, and the software composition is deficient in the curriculum; as a result, public schools are having difficulty implementing STEAM innovation education. As a result, STEAM deployment in China has been somewhat gradual (Wang, Xu & Guo, 2018). In Indonesia, educators and learners have commending attitudes toward careers and the value of STEAM education. Although students engaged in STEAM learning, the competences and circumstances that support and drive STEAM learning in schools remain limited. The educator lacked the necessary skills to integrate STEAM learning. This is due to the limited understanding of teachers about STEAM (Kartini & Widodo, 2020).

STEAM research in global is more big clusters than in South East Asia. STEAM research in global has 4 clusters that contains 62 keywords. In 2017-2018 the visualization of keyword usage was more and more widespread compared to 2019. The biggest keyword that used in STEAM research in global are program, project, environment, model, and implication. On the other hand, STEAM research in South East Asia has 2 clusters that contains 14 keywords. STEAM research in South East Asia has the biggest keywords at STEAM education. STEAM can be used in environmental-based education and integrate it with technology, such as making smart trash cans to improve the quality of the urban environment and provide convenience for the community (Rahmayanti, Oktaviani & Syani, 2018). Meanwhile, active STEAM education implementation must be supported by more valuable development programmes. Programmes with a project-based collaborative style have an impact on enhancing the ability to manage projects, think

critically, be artistically creative, and work in teams, making them extremely valuable for developing the skills and competences required in the 21st century. (Shatunova, Anisimova, Sabirova & Kalimullina, 2019). In research, Kim and Chae (2016) stated that STEAM can improve creativity and problem-solving skills in the national competitiveness of science so that STEAM can be used as a model and has a good influence on education.

Figure 5, explains that STEAM education in global related to experience, environment, project, case study, program, robot, module, etc. One of the application programs in STEAM education is AI (Artificial intelligence). How and Hung (2019) believe that AI can help STEAM students improve their AI literacy, allowing them to ask better questions and solve problems. STEAM education is frequently integrated with one of learning model, PjBL (Project Based Learning). Research conducted by Sooraksa, Sakorntanant, Jansri and Klomkarn (2020), using a robot as an instrument or learning media can assist students in achieving and improving 21st century learning. Students can engage in active collaboration, exploration of real-world challenges, and activity problem-solving when they create a STEAM project or conduct an experiment (Peppler, 2013; Liao, 2016; Wandari, Wijaya & Agustin, 2018; Hawari & Noor, 2020). Globally, STEAM education has a broader scope than in South East Asia. STEAM education in South East Asia is concerned with teaching, mathematics, science, activity, research, problem, students, etc.
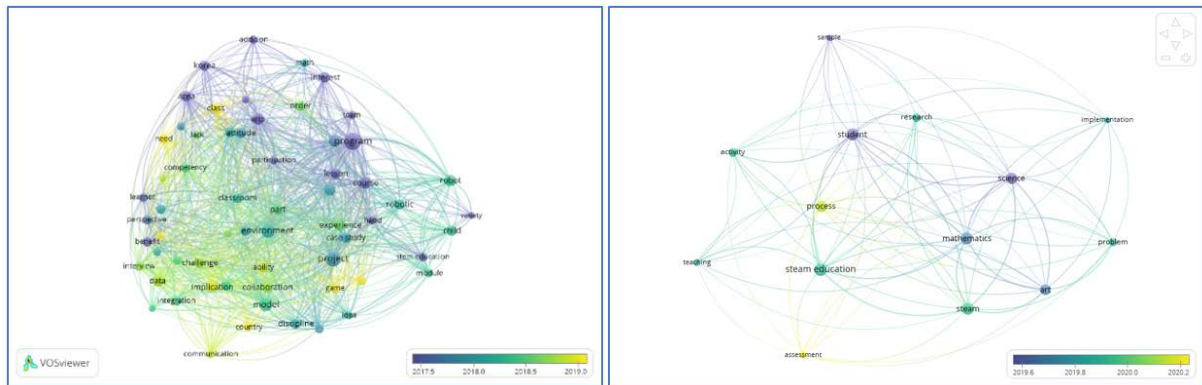

Figure 5. The visualization STEAM research in global (left) and South East Asia (right)
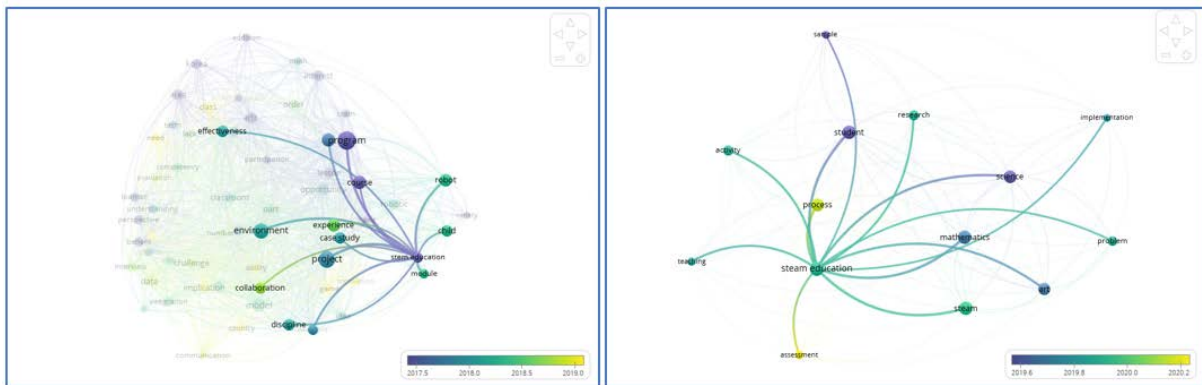

Figure 6. The visualization STEAM education in global (left) and South East Asia (right)

STEAM research in global has the largest cluster, project's cluster, which includes robotic, program, collaboration, and STEAM education. The keyword "program" and "project" are linked. The "project" keyword refers to students' assessment, so "project" has linked to model, classroom, evaluation, learner, collaboration, course, and steam education. The "program" keyword has linked to the "project" keyword. As a result, many STEAM research around global have discussed STEAM in education, how to develop STEAM in education with some model learning and subject, and how it affects to students' experience and communication. In STEAM learning, when students work on a project, they integrate

their knowledge in a way that facilities linkages between subjects and ideas that at first glance appear to be unrelated.
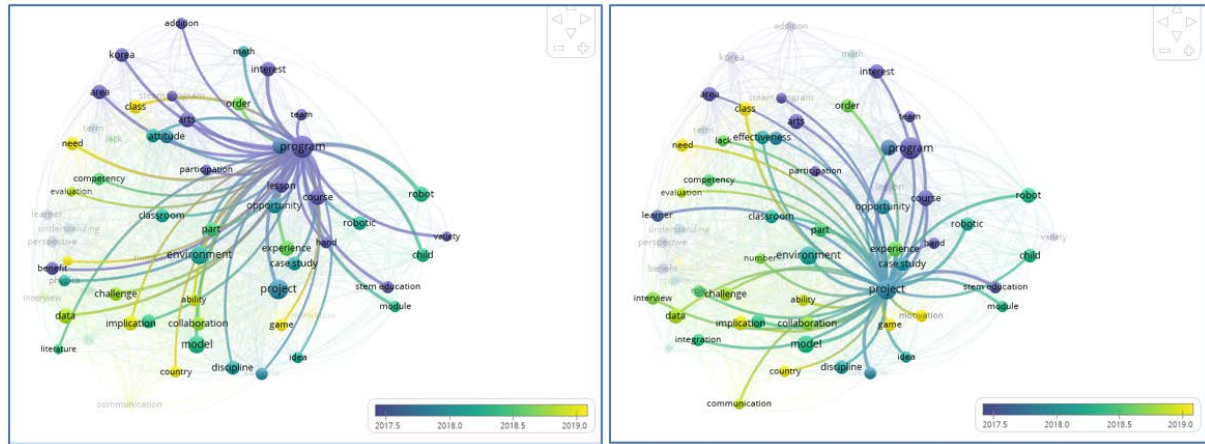

Figure 7. The visualization of program (left) and project (right) as the biggest cluster keyword in global

According to Sochacka, Guyotte and Walther (2016), STEAM allows educators and learner to investigate the connections between personality, environment, and society through cross-disciplinary study. Research conducted by Mariana and Kristanto (2023), Hawari and Noor (2020), Song, Kim, Song, Yoo, Lee and Yu (2019), STEAM education is aligned with project, program, and case study to improve students' soft skills such as computational thinking, collaboration, create something that solves problem. STEAM education integrated with project especially technology can provide to improve the learning satisfaction and cognitive learning outcomes, as well as arouse their learning motivation (Hsiao & Su, 2021). The STEAM model favors in the long run for the growth of scientific careers as well as the development of 21st century skills including collaboration, problem-solving, critical thinking, creativity, talent development.

4.7. Difference and Similarities Between STEM and STEAM

The results of the study of literature and scientific sources related to STEM and STEAM topics are obtained by the fact that each has differences and similarities in their respective fields.

STEM	STEAM
Difference	
• Focus more on Science, Technology, Engineering and Mathematics. • Does not integrate art in it. • The point of view is not to the point of art, music, and writing. • Non-art-based learning approach	• Focus more on Science, Technology, Engineering, Arts and Mathematics. • Integrate art in it. • The point of view has to be art, music and writing. • Art-based learning approach
Similarities	
• Process and project-based learning • Learning focuses on 21st century skills • An integrated learning approaches • Facilitate a dynamic, relevant and comfortable learning environment • Utilise technology	

Table 7. Difference and similarities between STEM and STEAM

4.8. Advantages and Disadvantages of STEM and STEAM

Advantages	Disadvantages
STEM	
STEM topics is Science, Technology, Engineering, and Mathematics.	Focus topic make student majority use his left brain.
STEM is a recommended learning for focus in science, technology, engineering, and mathematic.	Other discipline can't focus to use STEM like as linguistic, and design etc. (Guyotte, Sochacka, Costantino, Walther & Kellam, 2014; Rolling, 2016; Good, Bourne & Drake, 2020).
subjects of STEM are primarily characterized by realistic and investigative interests (Florian, Mouton & Ertl, 2022)	Student doesn't have imaginary thinking about object who never They meet.
STEM have many analyzed for six areas focus of it. Like as pedagogical, assessment and curricular (Le, Tran & Tran, 2021)	Analysed From STEM can make student more discipline but make them rigid personal.
STEM integrate with other different disciplines (Sanders & Wells, 2006)	Component integrates without art
STEM teaching and learning more aspect like conceptual, procedural, and attitudinal.	Complicated for teacher and student who used a simple technology.
STEM research not only educators whom use it but other side like a policy makers, business and industry join this research topics (Sutaphan & Yuenyong, 2018)	STEM education without artist or art enthusiastic.
About learning and teaching who use STEM model can apply with inquiry-based learning (Sutaphan & Yuenyong, 2018)	STEM can't do with PjBL models.
STEM should do with community practice (Kelley & Knowles, 2016)	A personal practice can difficult to practice with STEM.
STEAM	
STEAM topics is Science, Art, Mathematics, Technology, and Engineering.	Students who want a be focus with one side thinking have another difficulty if they study about art.
STEAM make a student way of think can balance because mix an intellectual, lively, and performance of effectivity (Sutrisno & Verhaak, 1993).	Characteristic of Person who have Introvert attitude become not comfortable zone with STEAM output be an extrovert person.
STEAM combine about imaginary from Art (Right Brain) and realistic from Science (Left Brain). Itmake integration of creativity and change STEM model become STEAM (Burnard, 2015)	An imaginary is urgent but sometimes they must be a focus with realistic topics not every situation use an imaginary side.
STEAM model can make model of curriculum be a creative. Because it make student be a creative scientist and innovative solutions (Madden, et al., 2013)	Creative scientists for a many people who have extrovert character. But other side, scientist's person has an introvert character that make them alone in they room.

Table 8. Advantages and Disadvantages of STEM and STEAM

Based on the Table 8 about advantages-disadvantages STEM and STEAM. Both of them make complete. STEM and STEAM can grow together with each subject and models. Because in other place, can apply with STEM education but can't STEAM and other place can apply with STEAM education but can't STEM. Some regions are focus with art but other region focus without art. But with grow mindful of student, STEAM use a right brain and left brain because mix about Science and Art. That can make student be a more extrovert but STEM can balance it to make student stay who basically introvert and can make student who want be an extrovert. STEM is the first than STEAM but for now, each other grow with each research enthusiastic.

4.9. Literature Review Top Cited Articles About STEM and STEAM

Authors	Source	TC	Finding	Recommendation/Limitation
How & Hung, 2019	Education Sciences	36	AI-Thinking could be taught to STEAM students, thereby improve AI literacy, which enables them to pose more pertinent questions and solve problems more effectively.	STEAM instructors could use these simulations to in still AI-Thinking in their students, possibly through discussion forums and then encouraging each team to review with the instructor and the rest of the class components.
Anito & Morales, 2019	Universal Journal of Educational Research	13	Philippine HEIs can advance by focusing on the development of critical job capabilities that meet existing labour market demands and predict developing and future labour market demands.	Philippine HEIs might investigate a more flexible and diverse infrastructure of talents and experience, as well as non- traditional modes of instruction.
Hawari & Noor, 2020	Asian Journal of University Education	11	PjBL approach assists teachers and students in developing authentic art lessons while also helping students by stressing the aesthetic challenge inherent in STEAM project construction.	The findings of this study could indeed assist educators in evaluating the approach's efficiency and thus clarify the progress of the educational practices, as they provide crucial insights to assist curriculum designers and academia in monitoring the efficiency of the PjBL approach as a pedagogical strategy in a variety of educational settings, primarily schools and higher education institutions.
Belbase, Mainali, Kasemsukpipat, Tairab, Gochoo & Jarrah (2021)	International Journal of Mathematical Education in Science and Technology	8	Curriculum integration as a means of educational reform was one of the sub-constructs under the priority of STEAM education. The educational procedure and evaluation in STEAM education were sub-constructs of STEAM education as a process. The difficulties were concerns of STEAM education.	Recommendation STEAM education professionals strive to establish and develop ecofriendly sustainable, compassionate, and equitable STEAM-h programs, regulations, and practices.
Talib, Aliyu, Zawadzki & Ali (2019)	Cite as: AIP Conference Proceedings 2184, 030003 (2019)	3	Graphic calculator is effectively integrated into STEAM education will help students built computational thinking skills as well as computer science skills beyond sorting and searching.	• Recommendation in secondary school chemistry teachers should receive professional development training on computational-based instructions and modern technology using GC. • Policymakers should emphasis GC as component of STEAM in secondary school. • Curriculum developers should produce materials that focus on integrating GC in the classroom instructions.

Table 9. Review Top Cited STEAM Research in South East Asia

Authors	Source	TC	Finding	Recommendation/Limitation
Peppler, 2013	Computer	163	The author has created a paper programming kit. By utilizing conductive and insulating dough, offer greater natural and enjoyable ways for children of all ages to make circuits and learn electronics. creating a new frontier for STEAM education to discover.	Technological developments, materials, techniques, and products at the nexus of the STEAM disciplines have the potential to change computing instruction and have repercussions throughout any of these sectors.
Liao, 2016	Art Education	198	An arts-integrated approach to STEAM education validates the innovative thinking, teaching 21 century communication and interpersonal skills and teamwork through the creative process.	Teachers develop a transdisciplinary setting with their own STEAM classes by providing projects that integrate many disciplines and thus feed students' capacity for knowledge transfer across fields.
Madden et al., 2013	Procedia Computer Science	211	The author, has established an interdisciplinary framework that integrates studies STEAM fields to stimulate creative thinking. The curriculum offers a solution to meet the complex problems confronting human society.	This innovative STEAM program may serve as the basis for educate inventive scientists capable of developing novel answers to pressing international issues. Once presented and critically assessed, this will be widely distributed all across the higher education sector.
Sochacka et al (2016)	Journal of Engineering Education. January 2016, Vol. 105, No. 1, pp. 15-42	146	The potential for STEAM to provide students and educators with opportunities to explore personally important linkages within elements, design, community, and the eco - systems, as well as proactively engaging with direct and indirect aspects of disciplinary character	Build on perspectives to continue a conversation about STEAM that highlights the various contributions of, and mutual benefits to, all parties involved.
Park, Byun, Sim, Han & Baek.(2016)	Eurasia Journal of Mathematics, Science & Technology Education, 2016, 12(7), 1739-1753	138	To help encourage STEAM education, the majority of Korean teachers had a supportive insight into the role of STEAM education and had appropriate government backing. Moreover, the education system should be reconstructed, and significant modifications towards the nationwide assessment system should be undertaken..	The main focus was on educators' viewpoints, however a comprehensive examination of all stakeholders, along with principals, parents, and students, is an access point for further research. Most significantly, future study should investigate how STEAM education fulfills its claimed aims by analyzing learners' motivation in learning science and mathematics.

Table 10. Review Top Cited STEAM Research in Global

5. Conclusions

This analysis of the keywords "STEM" and "Science Education" in the top citation of 100 articles during 2012 and 2022. There are 59 publications, 37 conference papers, two editorials. Meanwhile, the author with the most citations is Jeon M from the United States of America (39). The most articles were published in 2018, with eleven articles in the geographical area region and twenty articles globally. The United States of America (USA) has the most publications (31 articles with 2553 citations). Terms are widely utilized are communication, world and mathematics in Southeast Asia. Supported the visualization analysis. VOSViewer's global region is divided into four clusters and sixty-two keywords to assist with the visualization analysis. A pair of clusters containing fourteen keywords each for the South Asia region. The

terms "program," "project," "environment," "model," and "implication" are frequently used in STEAM throughout the world. The keyword STEAM education appears in analyses conducted in South-East Asia. STEAM education is associated with a variety of factors including experience, environment, projects, case studies, programs, robotics, and modules. One of the STEAM curricula is dedicated to artificial intelligence (AI). The development of students' skills in the area of science, technology, engineering, art, and mathematics as well as their ability to think critically and creatively to solve problems through cooperative teamwork is all impacted by the importance of STEAM education research. The outcome of this research can serve as a resource for scholars interested in STEAM and education. Further research into STEAM education trends can be conducted by focusing on a single region or on more specific issues. This information can all be used as a guide for various institutions to support training initiatives that enhance the teaching and learning processes of various disciplines. Additionally, it may support educational strategies that provide learners to synthesizing the information from the information from several fields of study.

6. Research Implication

The visualization of each cluster, both in global and in Southeast Asia, can be used as a starting point for future STEAM research to generate ideas and preliminary explanations for studies on the topics. This study gives librarians, researchers, and policymakers around the world new information to help them advance STEAM research and create a full Scopus document. The study additionally provides librarians, researchers, and policymakers with insight and information regarding research trend profiles in Scopus documents. Librarians and researchers may conduct more in-depth analysis and communicate with other universities to enhance publications and resources for future STEAM research. Furthermore, policymakers might re-plan the implementation of STEAM policies in an education system that has not yet been fully transformed in order to respond to contemporary societal issues and opportunities.

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