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Trend Research on STEM Learning Trough Bibliometric Mapping Analysis: Contribution to Science Education Undergraduate Program

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Abstract: This study aims to analyze the trend of STEM research publications in undergraduate education each year, visualize the trend of STEM research in undergraduate education, and how STEM research contributes to undergraduate science education. This study was conducted in September 2023 using bibliometric analysis. This study uses the following search terms in the title, abstract, and keywords: "STEM Learning" AND "undergraduate". The researcher only considered scientific articles published each year and did not limit the publication source. The initial data analysis resulted in 116 documents, then there were 109 documents that were relevant to the search criteria. The documents were analyzed using VOSViewer and Biblioshiny. The data was documented in (.csv) format. Next, this data was processed and analyzed using the VOSViewer and Biblioshiny applications to analyze the trend of research on STEM in undergraduate education programs.

Keywords: *STEM learning, bibliometric, Science Education Undergraduate Program*

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Introduction

Science, Technology, Engineering, and Mathematics (STEM) is becoming increasingly important in the field of education and is gaining widespread attention from educators and stakeholders alike (Gui et al., 2023; Kayan-Fadlelmula et al., 2022). STEM education has the advantage of being able to train 21st century skills such as critical thinking, creativity, and technology (Y. Li et al., 2016; Wahono, Lin, et al., 2020). Further explained, STEM that is applied in learning can develop scientific thinking skills and encourage the use of technology, motivate learners in learning, improve conceptual understanding, and help learners communicate and collaborate (Chittum et al., 2017; Gede Sandi, 2021; Han et al., 2016). Some other studies have also proven that STEM supports creativity in solving challenging problems. The application of STEM emphasizes innovation, creativity, and high-level thinking skills. STEM can also improve critical thinking skills and problem-solving skills (Astuti et al., 2021; Barry et al., 2018; Kurup et al., 2019; Yunian Putra & Indriani, 2017).

Bardoe et al. explained that STEM provides significant contributions to education. Through science, students can gain in-depth knowledge about their surroundings. Through technology, students will have better skills. Through engineering, students can solve problems. And mathematics helps students develop their capacity in analyzing information, reducing errors, and wisely reviewing the solutions taken (Bardoe et al., 2023). Education STEM is a learning that

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combines rigorous academic concepts with real-world learning (Samsudin et al., 2017). STEM education provides benefits to students to explore their creativity in solving a problem through several disciplines of science (Wahono, Chang, et al., 2020).

STEM education has been widely implemented in various levels of education (Darmawansah et al., 2023; Susanta et al., 2023). From primary education to higher education (Abouhashem et al., 2021; Larkin & Lowrie, 2023; Olewnik et al., 2023, 2023; Susanta et al., 2023). This proves that STEM has contributed a lot to the world of education. Therefore, STEM education has been widely adopted by many countries. For example, the United States is the country that has adopted the most STEM education and conducted research on STEM (Jamali et al., 2023; Wahono, Lin, et al., 2020). In Asian countries, research on STEM education has made a significant contribution. Wahono et al. found that STEM education in Asian countries is effective in improving student learning outcomes. Learning outcomes are focused on high-level thinking skills. Many people are varying STEM education to make it more innovative, for example by integrating STEM and projects, even projects are one of the recommendations that are prioritized in STEM education (Çevik, 2018; Wahono, Lin, et al., 2020).

Research Questions

The research focuses on the trends of STEM research, namely:

a. To what extent is the profile of STEM publications output in undergraduate education in multi year?
b. To what extent is the distribution of STEM publications in undergraduate education between countries and affiliations in the world?
c. Who are the main authors in STEM research in undergraduate education in the world?
d. How to visualize the trends of STEM research in undergraduate education?
e. To what extent does STEM research contribute to undergraduate science education?

Research Methodology

The research conducted a systematic review of published empirical studies to identify research on STEM in undergraduate education. This systematic review used bibliometric methods adapted from Kulakli & Osmanaj; Yang, dkk; Bonilla-Chaves & Palos-Sánchez (Bonilla-Chaves & Palos-Sánchez, 2023; Kulakli & Osmanaj, 2020; Yang et al., 2017).

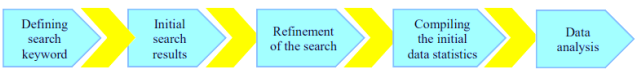

Figure 1. Five steps in conducting bibliometric analysis (Ari Masitoh et al., 2021; Suprapto et al., 2021)

Literature search was conducted in September 2023 using the Scopus database. The study used the following search terms in the title, abstract, and keywords: "STEM Learning" AND "undergraduate". The researcher only considered scientific articles published each year and did not limit the publication source. The initial data analysis resulted in 116 documents, then 109 documents were relevant to the search criteria. The documents were analyzed using VOSViewer and Biblioshiny. The data was documented in (.csv) format. Next, this data was processed and analyzed using the VOSViewer and Biblioshiny applications to analyze the trends of research on STEM in undergraduate education.

Result and Discussion

STEM research output profile in undergraduate education in multi year

The results of the search for scientific articles relevant to STEM research in undergraduate education in the Scopus database obtained 109 documents. This publication analyzes publications in each year (multi years) can be seen in Figure 2, which shows that research on STEM in undergraduate education tends to fluctuate. In 2021, STEM research in undergraduate education showed the most research output, with a total of 16 articles (see Figure 2).

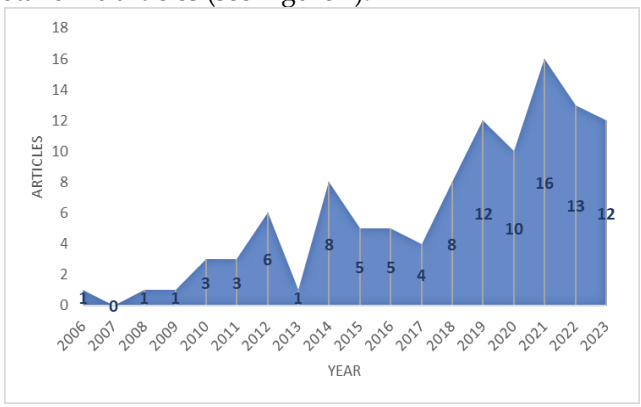

Figure 2. The number of STEM research documents in undergraduate education

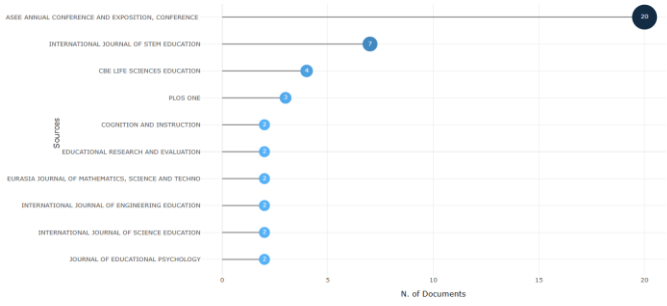

Figure 3. Top ten most relevant sources of STEM research in undergraduate education

Figure 3 shows that the most STEM research in undergraduate education is published in the ASEE Annual Conference and Exposition, with 20 documents.

Distribution of STEM research publications in undergraduate education across countries and affiliations in the world

Based on the number of documents between countries, it is clear that the United States ranks first with 11 documents, followed by China in second place with 10 documents. Some researchers conduct research in collaboration between countries (MCP), and also in collaboration with one country (SCP). It is seen that the authors who have established international research collaborations are Hong Kong, India, Italy, Spain, Georgia, Greece, Singapore, and Colombia. While the USA, China, Australia, Japan, and other countries including Indonesia are still collaborating only in that country.

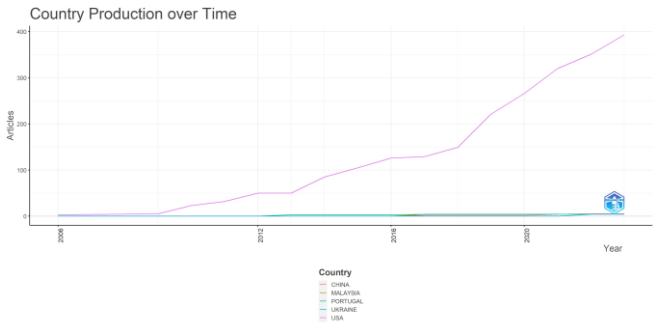

Figure 4. STEM research by country

Figure 4 shows that the United States is the most productive country in producing research on this topic. It has even been increasing every year. In addition to the United States, other countries such as China, Ukraine, Portugal, and Malaysia are also actively conducting research on STEM learning in higher education.

Based on the number of documents analyzed that are spread across all institutions, it can be seen in Figure 5 that the University of Washington is the institution that produces the most research on STEM learning in undergraduate education, with 17 documents. Followed by the University of Minnesota, which ranks second with 16 documents. In third place is Florida International University with 11 documents..

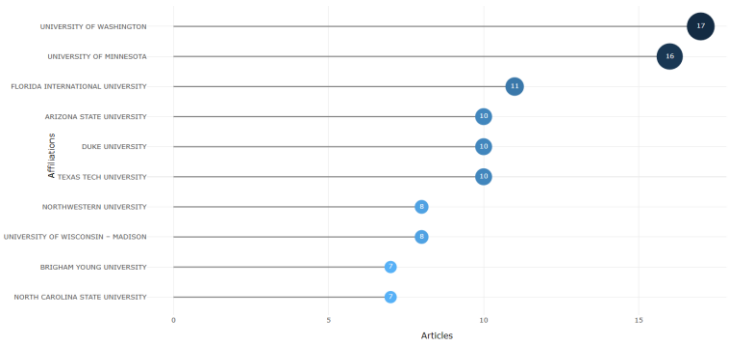

Figure 5. Top ten most dominant institutions in STEM research

Table 1. Top Ten Institutions Producing the Most STEM Learning Research in Undergraduate Education

The main authors in STEM learning research in undergraduate education around the world

In terms of the most productive authors researching STEM in undergraduate education, Figure 6 shows the number of authors who produce the most on the topic. The blue dot shows the number of publications, the larger the size of the circle, the more publications it has. Meanwhile, the color density shows the number of citations, the more intense the color, the more citations it has. Hasan MR is the most productive author in producing research on STEM education this year, with 2 documents.

No	Affiliation	Articles
1	UNIVERSITY OF WASHINGTON	17
2	UNIVERSITY OF MINNESOTA	16
3	FLORIDA INTERNATIONAL UNIVERSITY	11
4	ARIZONA STATE UNIVERSITY	10
5	DUKE UNIVERSITY	10
6	TEXAS TECH UNIVERSITY	10
7	NORTHWESTERN UNIVERSITY	8
8	UNIVERSITY OF WISCONSIN – MADISON	8
9	BRIGHAM YOUNG UNIVERSITY	7
10	NORTH CAROLINA STATE UNIVERSITY	7

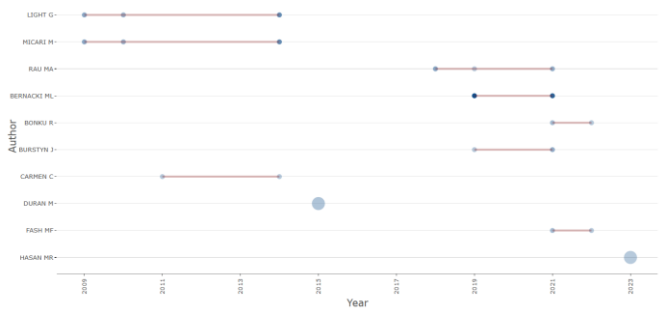

Figure 6. The most productive authors in STEM research

Based on the number of citations, the author with the most citations is Bernacki ML, with 34 citations. In second place is Light G & Micari M, with 33 citations. Each of the publications cited is from a journal. Light G & Micari M also takes third place, with 26 citations.

Table 2. Top citation of article/document

No	Author	Source	∑citation
1	Bernacki ML	Journal Of Educational Psychology	34
2	Light G & Micari M	Educational Research And Evaluation	33
3	Light G & Micari M	International Journal Of Science Education	26

Visualization of the results of STEM learning trends in undergraduate education

Based on the analysis of 109 articles related to STEM learning in the Scopus database, researchers can produce findings about the thematic map through the biblioshiny application. This study analyzed the thematic map by dividing it into four thematic quadrants based on density and centrality. Themes in the upper right quadrant should be developed and studied further because of their high density and centrality. Conversely, specific, rare, but highly developed themes with high density and low centrality are in the upper left quadrant. Next, themes with a declining trend are in the lower left quadrant, while fundamental themes with high centrality but low density are in the lower right quadrant. Thematic Map shows that STEM learning is still an interesting topic to develop in research.

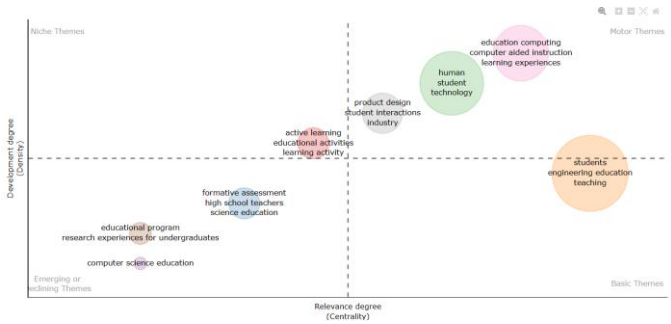

Figure 7. Thematic map

From the data above, additional testing will be carried out through the VOSViewer application. This helps to confirm the data from biblioshiny related to the novelty of research in this domain. Figure 8 shows an overview of research on STEM education. Researchers around the world produce three clusters (red, green, and blue).

Table 3 is the cluster that appears in the research trends with this topic

Cluster	Keywords
Cluster 1	Activity, addition, education, faculty, interest, math, mathematics, need, number, paper, problem, project, stem education, teacher, tool, training
Cluster 2	Change, context, environment, group, implication, instructor, outcome, practice, researcher, sense, study, support, type, undergraduate
Cluster 3	College, discipline, impact, intervention, part, performance, resource, stem discipline, teaching, year

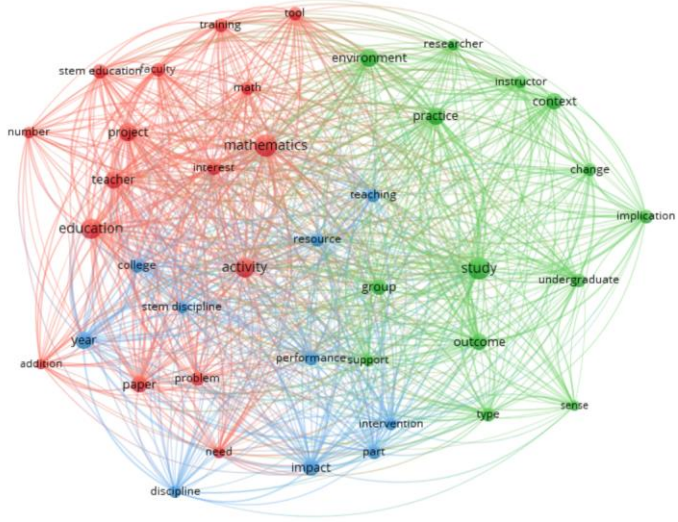

Figure 8. Thematic network of STEM learning research trends in undergraduate education

To determine the novelty of STEM education research, it can be done by outlining the specific relationships between variables. Figure 9 reveals this picture.

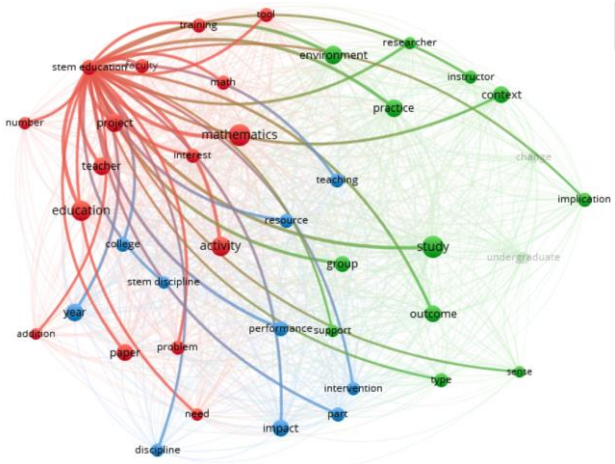

Figure 9. The relationship between STEM learning and other domains

Figure 9 shows that STEM learning research is related to undergraduate education, although there have not been many studies that have examined this, so it is an opportunity for researchers to examine this topic more deeply. In addition, STEM is related to projects, problems, education, and so on. Furthermore, STEM is related to performance, impact, and teaching.

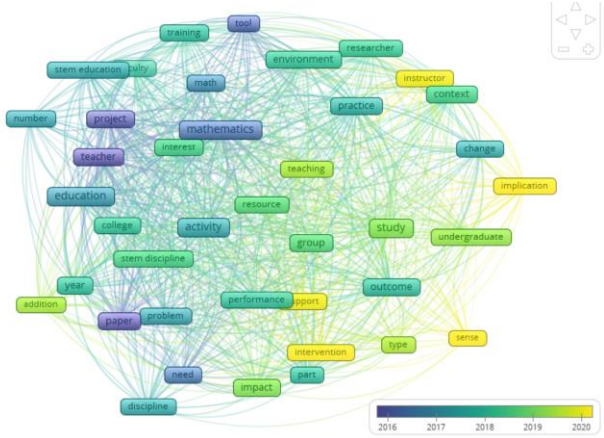

Figure 10. Thematic Map VOSViewer

Figure 10 shows that STEM-related keywords are widely used by researchers. In the latest year (in yellow), there are several themes that are still interesting issues to be studied until now. Future research can follow the latest topic trends, one of which is to study the impact of STEM in teaching.

The contribution of STEM learning research in undergraduate education

Based on the results of the document analysis obtained from the Scopus database and based on the results of the software analysis, it is concluded that STEM learning has a significant contribution in undergraduate education (Abouhashem et al., 2021; Olewnik et al., 2023). STEM learning in higher education contributes to the development of student skills. Many studies have been conducted related to STEM learning in the documents obtained. For example, the research conducted by Samsudin et al. that STEM is a learning that combines rigorous academic concepts with real-world learning (Samsudin et al., 2017). The results of Wahono's research, et al. STEM education provides benefits to students to explore their creativity in solving a problem through several disciplines of science (Wahono, Chang, et al., 2020). Furthermore, Lin et al. produced findings about STEM learning aims to prepare students with problem-based learning (Lin et al., 2023).

Bardoe, et al. explain that STEM makes a significant contribution to education. Through science, students can gain a deep understanding of their surroundings. Through technology, students will have better skills. Through engineering, students can solve problems. And mathematics helps students develop their capacity to analyze information, reduce errors, and wisely review the solutions taken (Bardoe et al., 2023). STEM education is a learning that combines rigorous academic concepts with real-world learning (Samsudin et al., 2017). STEM education can help students explore their creativity in solving problems through several disciplines of science (Wahono, Chang, et al., 2020).

STEM education in undergraduate programs is very influential in the United States. This is evident in the fact that the United States is the most productive country in producing research on this topic. China, Ukraine, Portugal, and Malaysia are also actively conducting research on STEM education in higher education. Based on the number of documents analyzed that are spread across all institutions, the University of Washington is the institution that produces the most research on STEM education in undergraduate programs, with 17 documents. This is followed by the University of Minnesota, which is in second place with 16 documents. The third place is held by Florida International University with 11 documents. Gursoy & Kakadiaris explain that the United States continues to maintain its leading role in research and development, especially in research on technology, particularly in the development of STEM education (Gursoy & Kakadiaris, 2023).

STEM education is still a trend of research that has not been developed much, especially in undergraduate programs, it is still a trend of interesting topics to be studied. The results of Wahono et al.'s research that STEM education provides benefits to students to explore their creativity in solving a problem through several disciplines of science (Wahono, Chang,

et al., 2020). Furthermore, Lin et al. produced findings about STEM learning aims to prepare students with problem-based learning (Lin et al., 2023). The results of Santhos et al.'s research produced findings that STEM learning through projects has a very big impact on student knowledge (Santhosh et al., 2023).

Conclusion

Based on the analysis results, the research results show that STEM learning has a strong correlation in undergraduate education programs. Considering the document type, conference articles are the most abundant source compared to other document sources. Furthermore, considering the country, the United States makes the most contributions to STEM research, followed by China, Ukraine, Portugal, and Malaysia. Considering the most productive author, this year Hasan MR is the most productive author producing research on STEM education. An interesting finding, STEM learning is still an interesting topic to be studied more deeply, especially in higher education.

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