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A Bibliometric Analysis of Problem-Solving Skill and STEM Integration in Education (Scopus Database 2004-2024)

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Abstract: Problem solving and STEM integration in education are important in many countries around the world. Problem solving and STEM integration in education can also be applied at various levels. This study aims to describe the development trends of research in the topic, as well as to identify the most relevant and widely cited countries, sources and topics in the related literature. Previous studies have shown that problem solving and STEM integration are mostly applied in secondary schools. In this study, we extracted from the Scopus database to analyze and evaluate the results of scientific publications related to problem solving and STEM integration in education during 2004-2024. The number of publication data that has been filtered is 106 publications, all of which are taken from the Scopus database. The results of the quantitative analysis show that research on problem solving and STEM integration in education has grown rapidly in the last 5 years. The most relevant and most cited country is the USA. Meanwhile, the most relevant source is CBE Life Sciences Education. The research topics are also quite diverse, focusing on several issues: engineering, education, humanism, professional aspect, etc. This research has limitations, because the publication data we analyzed was only data from Scopus and the analysis we used used VOSviewer and biblioshiny.

Keywords: Education; Problem solving; STEM;

Introduction

At this time, students in their development must be able to prepare for the various challenges that exist in the future, namely with an inquiry, scientific, and practical approach in the field of engineering that can provide students with adaptation to various conditions and problems that exist. (Le Thi Thu et al., 2021). Problem solving is one of the thinking skills that must be possessed in 21st century education, because problem solving skills are needed to solve all problems that arise. (Riyadi et al., 2021). From a psychological point of view, problem solving can be perceived as a condition that includes difficulties and challenges, thus making individuals actively seek resolution. (Rasyid et al., 2023). STEM education is a contemporary, multidisciplinary approach that adopts problem-solving skills for today's generation of innovative individuals. (Hebebcï and Usta, 2022).

STEM skills can determine a country's ability to compete with other countries depending on the number of individuals specialized in business. In order to increase the number of individuals, it is necessary for the education system to give responsibility to each individual, provide space to channel the way of thinking, equip information and communication technology from childhood, and equip individuals with entrepreneurial spirit and creative spirit and problem solving skills that continue to increase every day. (Karisan et al., n.d.)

Scientific quantitative analysis research of STEM education in the world can use the Web of Science database (Özkaya, 2019). Some of these studies have described the development of research on problem

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solving and STEM integration in education more extensively. In this decade, all studies confirm that problem solving and STEM integration research is growing rapidly. From the data analysis of scientific publications in this field, we can see that research on STEM integration in education has increased rapidly in recent years in developed countries and has a positive impact on the development of students' problem solving. Even the practice of integrated STEM education has a positive impact on learners' problem solving skills, which is supported by many studies with similar results in the literature (Kopcha et al., 2017).

In addition, STEM education does not address students' problems from a single perspective, allowing them to view them from an interdisciplinary perspective (Texas A&M University et al., 2013).

In this research, we want to learn about problem solving and STEM integration in education. For the main purpose of this study, this research is designed to answer the following questions :

RQ1 What is the general information and annual scientific production of publications related to the fields of problem solving and STEM integration in education?
RQ2 What is the corresponding author's countries in the research field?
RQ3 What is the most cited countries in the research field?
RQ4 What is the most relevant sources in the research field?
RQ5 What is the most important and popular research topic in this field of study?

The results of this study will provide an overall picture of problem solving and STEM integration in education. For researchers, regulators and policy makers, this information is of great interest to develop a good vision in the coming years.

There are five main bibliographic databases that can be used to conduct a bibliometrics analysis, including: Scopus, Google Scholar, Web of Science (WoS), Microsoft Academic and Dimentions (Moral-Muñoz et al., 2020a). Among them, we use the Scopus database because it can search more data than others. (Mongeon and Paul-Hus, 2016).

Method

In general, science workflow mapping is divided into 5 stages: (1) Learning design; (2) Data collection; (3) Data analysis; (4) Data visualization; and (5) Data interpretation. (Börner et al., 2003). In the learning design stage, the main research question was: What was the bibliometric of publication in problem solving and STEM integration in education, indexed in the Scopus database during 2004-2024? Data collection stage is divided into three sub-stages: data collection, data filtering and data cleaning.

Step 1: Data collection. The authors searched for data from the Scopus database (http://www.scopus.com), by entering several keyword options according to the search data syntax on September 4, 2024. Keyword searching for problem solving and STEM integration in education was completed according to previous research: "problem solving" with words (stem* AND integration* AND education*). The character "*" represents any group of characters in Scopus data search syntax. The search is limited to abstract, keyword and title of document. Year of Publication is selected for the period from 2004 to 2024. Limited data about Document type is articles, reviews, book chapters, editorial and letters in the field of social sciences, written in English language.

Step 2: Data filtering. In this stage, we filtered the data by filtering titles, abstracts and keywords, removing material that was not directly related to problem solving and STEM integration. The material that was removed was usually related to the verb "stem" found in biological science and the word "problem" found in problem-based learning.

With some existing data, we performed some preliminary analysis on the journals using Scopus tools to gather additional information on authors, affiliations and journals. Then the final publication data collection was exported to two different formats for post processing in two of the most popular and effective bibliometric analysis tools, CSV format for VOSviewer tool (Van Eck and Waltman, 2010) and BIB format for Biblioshiny tool (Moral-Muñoz et al., 2020b). Additional information on the Scopus website and from Scimago Journal & Country Rank (https://www.scimagojr.com/) (accessed on September 8, 2024) was also used to support the analysis.

The data collected before further analysis, presented the query String data from the Scopus database shown in Table 1.

Table 1. Data collection results from the Scopus database

Query Strings	Results	Filtered	Data Collected
(TITLE-ABS-KEY ("problem solving") AND TITLE-ABS-KEY (stem AND integration) AND TITLE-ABS-KEY (education)) AND PUBYEAR > 2003 AND PUBYEAR < 2025 AND (LIMIT-TO (OA , "all")) AND (LIMIT-TO (SUBJAREA , "SOCI"))	443	337	106

Data collected from Scopus database (http://www.scopus.com), accessed on 4 September 2024.

Step 3: Data cleaning. The data that has been accumulated needs to be cleaned because the quality of the analysis is highly dependent on the quality of the input data. For example, there are several institutional names that are listed multiple times, even though they are affiliated.

Several analysis techniques have been applied to extract information from several sets of publications. General information of the publication was and annual scientific production was analyzed to draw the growth trend of research field. This study analyzed the publications related to problem solving and TEM integration in education in the time span of 2004-2024, where the contribution of writing has increased and decreased as seen in the data. The number of countries relevant to problem solving and STEM integration research. There are a total of 20 countries that are relevant and related to this research. And the top 10 most cited countries with citation data per publication. When performing the author affiliation statistics, we used some important information from authors regarding recent publications, as some authors have changed affiliations in recent years. Research design and method should be clearly defined.

Result and Discussion

Result

General Information and Annual Scientific Production

The most important information of the collection in the field of problem solving and STEM integration in education are shown in Table 2. The authors have listed the publications in the period 2004-2024, but the first publications on the fiels appeared in 2007. In the period from 2007-2024, the authors published a total of 106 publications. The majority were articles with 75 publications (70.8%), the conference paper for 19.8% of publications and the reviews for 6,7% of publications. The book chapter, editorial and letter respectively only accounted for 0,9% of publications. The publications are published on 73 different Scopus sources (journal, books, etc.).

A total of 400 authors have appeared in the collection of 106 publications, in which the number of Authors of single-authored documents is 15. The authors collaboration consist to the Single-authored documents is 16 and the ratio of Co-Authors per Documents is 3.91.

Information on annual scientific production of publications is shown in Figure 1. In Figure 1 the annual data on scientific production from 2007-2024 has increased, although in 2004 it decreased slightly because the data collection was still in September in 2004. In 2007 there was only 1 article, starting to increase in 2015, namely 10 articles. Then in 2021 to 2022 it increased from 9 articles to 15 articles and in 2023 it experienced the highest peak, namely up to 17 published articles.

Table 2. Main information of the publication collection.

Description	Results
MAIN INFORMATION ABOUT DATA	
Timespan	2007:2024
Sources (Journals, Books, etc)	73
Documents	106
Average citations per doc	14.62
References	5081
DOCUMENT TYPES	
Article	75
Conference Paper	21
Review	7
Book Chapter	1
Editorial	1
Letter	1
AUTHORS	
Authors	400
Authors of single-authored docs	15
AUTHORS COLLABORATION	
Single-authored docs	16
Co-Authors per Doc	3.91

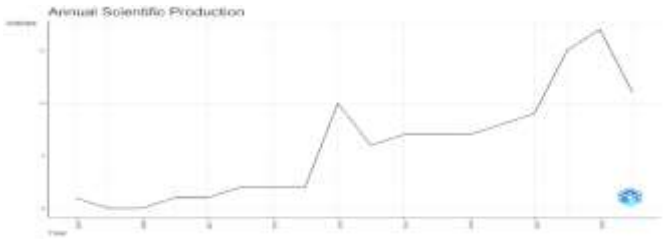

Figure 1. Graph of annual scientific production. Graph generated by Biblioshiny.

The Corresponding Author's Countries

There are 20 most relevant countries in publications related to problem solving and STEM integration in education. The country data of the relevant authors are shown in Figure 2. The USA has the most publications related to problem solving and STEM integration in education.

Figure 2. Corresponding Author's Countries. Graph generated by Biblioshiny.

The percentage of single country publications (SCP) and multiple country publications (MCP) is shown in table 3. Table 3 shows the top 7 corresponding author's countries. The USA with a total of 32 articles (30.2%), with a SCP ratio of 30 articles and MCP 2 articles (6.3%). Followed by Spain with a total of 7 articles and Ireland with 2 articles. The next four countries are Belarus, Nigeria, Sweden and the United Arab Emirates with 1 article each and a total of 1 MCP article (100%).

Table 3. Top 7 Corresponding Author's Countries

Country	Articles	Articles %	SCP	MCP	MCP %
Usa	32	30.2	30	2	6.3
Spain	7	6.6	6	1	14.3
Ireland	2	1.9	1	1	50
Belarus	1	0.9	0	1	100
Nigeria	1	0.9	0	1	100
Sweden	1	0.9	0	1	100
United Arab emirates	1	0.9	0	1	100

The Most Cited Countries

An overview of the most cited countries is shown in Figure 3. There are 10 top countries that are the most cited countries. The highest ranked country is the USA.

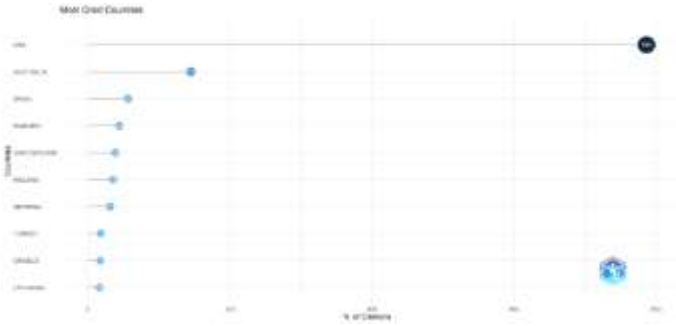

Figure 3. Most Cited Countries. Graph generated by Biblioshiny.

The average cited article data from the top 10 most cited countries is shown in table 4. The first rank is the USA with a total of 786 citations per year (TC) and an average article citation of 24.60. The next country is Australia with a total annual citation (TC) of 145 and the average article citation is also 145.00. Followed by Spain with TC 56 and average AC 8.00, Sweden with TC 44 and average AC 44.00, Switzerland with TC 38 and average AC 19.00, Ireland with TC 35 and average AC 17.50, Georgia with TC 31 and average AC 15.50, Turkey with TC 18 and average AC 6.00, and Greece with TC 17 and average 5.70. Furthermore, in 10th place is the country of Lithuania with a TC of only 16, but an average AC of 16.00 which is higher than the countries of Spain, Turkey and Greece.

Table 4. Most Cited Countries

Country	TC	Average Article Citations
Usa	786	24.60
Australia	145	145.00
Spain	56	8.00
Sweden	44	44.00
Switzerland	38	19.00
Ireland	35	17.50
Georgia	31	15.50
Turkey	18	6.00
Greece	17	5.70
Lithuania	16	16.00

The Most Relevant Sources

Information on the most relevant sources for publications on problem solving and STEM integration in education is shown in Table 5. There are 10 top data related to the most relevant sources. The top data of the most relevant source is CBE Life Sciences Education with a total of 7 articles. The next source is Education Sciences and Sustainability (Switzerland) with the same number of articles, namely 6 articles, and the International Journal of STEM Education with 4 articles. Furthermore, sources from Frontiers in Education, Journal of Advanced Academics, Journal of Physiscs: Conference Series and Proceedings of SPIE- The International Society for Optical Engineering with the same number of articles, namely 3 articles. And finally sources from ACM International Conference Proceeding series and European Journal of STEM Education as many as 2 articles each source.

Table 5. The Most Relevant Sources

Sources	Articles
Cbe life sciences education	7
Education sciences	6
Sustainability (switzerland)	6
International journal of stem education	4
Frontiers in education	3
Journal of advanced academics	3
Journal of physics: conference series	3
Proceedings of spie - the international society for optical engineering	3
Acm international conference proceeding series	2
European journal of stem education	2

Keywords and Terms Analysis

The co-occurrence network of 41 most popular keywords, which appeared at least four times, is presented in figure 5. Each keyword in figure 5 is represented by a node, and the thickness of the line between the two nodes is proportional to the strength of the relationship between them. This relationship can be

derived from the number of times the data between the nodes appear together in multiple publications. Interlinked keywords (or research topics) are assigned vertices of the same color and grouped in the same cluster. The interlinked keyword clusters are divided into 5 word clusters. The red group is a group that is bound and related to the main keyword problem solving, which includes the words problem solving skills, education, stem education, e-learning, high school, computational thinking, engineering. The green and yellow groups are groups of words related to the next keyword, STEM, which includes several words, namely: science, technology, engineering, female, male, human, mathematics, article, teacher, critical thinking, creativity, higher education. The blue and purple groups are words related to education, which includes several words, namely: problem-based learning, biology, educational model, university, communocation, thinking, engineering and mathematics, science technology and primary education.

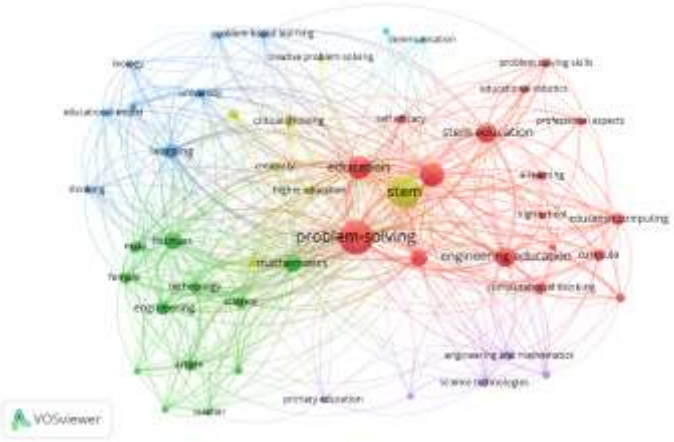

Figure 5. Co-occurrence network of 41 most popular keyword (at least four times). Artwork generated by VOSviewer.

Discussion

In this study, bibliographic data in the Scopus database can be used to explore the total number of publications that study and discuss problem solving and STEM integration in education over the past two decades (2004-2024). Research on problem solving and STEM integration in education has skyrocketed over the past five years. This can be seen in figure 1, although there is a slight decrease in 2024, this is because when the data collection was carried out in September which 2024 had not yet ended. The number of citations has steadily increased in recent years, as the number of studies on this topic has increased.

Research on problem solving and STEM integration in education was first conducted in 2007, then increased every year. The number of publications in this area between 2007-2016 was relatively low, with a total of 19 publications over 10 years (accounting for only 17.9% of the total number of publications in two decades). In the following period, the number of studies increased on the topic of problem solving and STEM integration in education with a total of 87 publications (accounting for 82.1% of the entire set of publications) (see figure 1).

Research in these two decades is mostly from the USA. This can be seen from the data that the USA has the most corresponding author's countries with a total of 31 articles (see table 3) and the most cited country compared to other countries with 786 citations per year (see table 4). Thus, it can be said that the USA has an important role in building scientific relationships between countries. This is also consistent with the analysis of problem solving and STEM integration publication output in general (Özkaya, 2019). In addition to this, the USA can be said to be a driving country in research on problem solving and STEM integration in education.

In the most relevant sources in research on problem solving and STEM integration in education, it can be seen that CBE Life Sciences Education is the most relevant source compared to other sources, namely 7 articles (see table 5). However, other relevant sources also published almost the same number of articles on average, around 2-4 articles.

The keyword analysis in Figure 5 shows that research topics on problem solving and STEM integration in education have diverse topics, focusing on several issues: engineering, education, human, professional aspect, etc. These issues are divided into five main groups that are all interconnected.

Conclusion

This research uses bibliographic data from the Scopus database to study the development of related publications on problem solving and STEM integration in education published over the past two decades. The main findings of this research are: 1. The number of publications continues to increase especially in the range of 2017-2023, along with the increase in the number of research published. 2. The USA is the most relevant country in corresponding author's countries. 3. The country most cited in the publication is the USA. 4. The most relevant source in research on problem solving and STEM integration is CBE Life Sciences Education.

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Author Contributions

Conceptualization, formal analysis by Reny Afifah (R.A), Ayu Mar'ati B. (A.M) and Heru Kuswanto (H.K); Reny Afifah (R.A), writing-early drafts, results and discussion; Ayu Mar'ati B. (A.M), methodology, supervision and review; Heru Kuswanto (H.K), supervision, conclusions and review.

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Conflicts of Interest

The authors declare no conflict of interest in the decision to publish the results.

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