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Systematic Review on Student's Problem-Solving Skills: A Bibliometric Analysis

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Abstract:- Problem-solving is a critical skill needed by an individual in life. This research aims to discover new areas of research related to problem-solving skills, identify main research topics, and analyze them in time order. In this research, a descriptive method was used. Data were collected through documentation studies from the Scopus database and bibliometric analysis on 501 academic articles related to problem-solving skills. The "Bibliometric" R Package was used to analyze the content. A performance analysis comprising five categories—annual scientific productivity, pertinent sources, prolific authors, highly cited publications, and pertinent keywords—is included in this research. Science mapping employed thematic analysis and country collaboration analysis. This research is seen as a comprehensive bibliometric insight into analyzing problem-solving ability studies so far. The results are believed to be useful in understanding research interests in problem-solving skills and further research.

Keywords*: Problem-Solving Skills, Bibliometric Analysis.*

1. Introduction

Problem-solving skills are very important in various contexts, namely business and the world of work, as well as education [1], [2]. In the dynamic and complex world of education, problem-solving is a basic skill in developing students' abilities [3]. Problem-solving is also a fundamental learning experience. These skills enable individuals to identify and address the root causes of problems, think analytically and creatively, and make effective decisions [2].

A person's ability to use cognitive processes to solve problems for which there is no obvious or straightforward solution is known as problem-solving skills [6]. Four steps are involved in fixing a problem: comprehending the issue, formulating a plan of action, carrying it out, and assessing the outcome Problem-solving skill is "heuristic" problem-solving that involves a trial and error process and the use of practical rules to reach a solution [12], [13]. Daily problem-solving skills are closely related to practical aspects as one of the three main aspects of intelligence, the other aspects being analyticity and creativity [14]–[17]. These abilities support individuals in their communication, self-confidence, and in transferring knowledge to different environments [18]. These skills need to be trained to increase the individual's ability to overcome problems [19].

Research related to students' problem-solving skills shows rapid growth. It is recorded that several researchers have made efforts to understand trends and dynamics as well as the impact of problem-solving in the educational context. The use of Systematic Reviews and Bibliometric Analysis in research is not something new as there have been a number of articles related to them. However, the use of bibliometric approaches and analysis of problem-solving skills has not been widely used, therefore this is worth studying. The systematic review, as a careful and structured methodological approach, is an effective tool for exploring scientific literature [20], [21] including students' problem-solving skills. By applying bibliometric analysis to a number of literature, the core of research can be identified, and the main parts of it be identified [22], [23], as well as evaluation of dominant research trends [24]–[26]. Systematic research such as in this research aims to provide a comprehensive understanding of research that has been carried out in the context of students' problem-solving skills through analysis of several aspects, such as most prolific authors, citation trends, and collaboration networks. Based on the results of this analysis, a strong research framework and certain areas or regions that require more attention can be identified.

Using literature systematization and a bibliometric approach, not only will we obtain an in-depth picture of the diversity of research regarding students' problem-solving skills, but it will also provide insights for decision-making in educational development that focuses on improving this domain of critical skills. This of course further strengthens the importance of this research. This research is expected to contribute to increasing understanding or additional knowledge about the dynamics of research on students' problem-solving skills, and future research directions, and providing a strong foundation or motivating the emergence of further research to improve education.

2. Students' Problem-Solving Skills and Research Lines

To analyze discussions related to students' problem-solving skills from various studies indexed by Scopus, a citation approach was used in this literature review based on the highest number of citations. Citations were used to measure the extent to which a study has influenced other studies and thoughts [27]. The number and quality of citations can indicate how important or influential the scientific work is in a certain scope [28]–[30].

The most frequent conversations on students' problem-solving abilities center on defining design thinking's traits and features as well as its significance for enhancing students' problem-solving abilities in the twenty-first century [31]. Design thinking is a creative and collaborative approach to solving complex problems and designing innovative solutions [32]–[34]. This kind of approach is not only used in product, service, and user experience design, but can also be applied in a variety of contexts, including business, the public sector, and education. Design thinking involves a series of steps or phases aimed at understanding a problem, identifying user needs, and developing better solutions.

The development of problem-solving skills is often associated with the use of digital-based games in learning. Analysis of learning shows that most digital games are used to increase students' scientific knowledge or concepts. The facilitation of problem-solving skills in students occurs through the use of various game variants or game approaches in learning, for example, the Game-Based Science Learning (GBSL) approach [35]. Various educational games offer the right strategy to develop problem-solving skills and create an interesting and more enjoyable learning atmosphere for students. This shows that educational games can well describe problem-based game processes in which the reflection phase seems to be an important factor [36], [37]. Additional studies on educational games examine how well Digital Game-Based Learning (DGBL) facilitates problem-solving. The results show that the DGBL strategy is effective in improving students' problem-solving skills [38]. The Use Your Brainz game (a modified version of the Plants vs. Zombies 2 game) is oriented toward measuring the problem-solving skills of middle school students [39]. Both the health and education sectors are seeing growth in the use of problem-solving techniques. The gap between theory and practice is a means to develop students' problem-solving skills [40]. In business class students, problem-solving skills are more easily developed with simulation approaches and case studies [41]. Problem-Based Learning methods (PBL) in small groups is a method that has been proven to improve problem-solving skills [42]. As in physics learning, the PBL approach which is relevant to everyday life is the best way to learn physics by improving problem-solving skills [43], in information technology learning, computer programming does not significantly improve students' problem-solving skills [44].

The development of research on problem-solving over 42 years (1981-2023) was identified and is presented in Table 1. In addition, Table 1 provides a Digital Object Identifier (DOI), which facilitates readers' exploration of publications and additional data required to assess problem-solving skills growth according to the greatest number of citations. Apart from the table, a chart is also presented to simplify the research flow.

Table 1. An overview of the scientific literature that has been reviewed

No	Paper	DOI	Total Citations (TC)	TC per Year	Normalized TC
1	RAZZOUK R, 2012, REV EDUC RES	10.3102/0034654312457429	565	47.08	9.62
2	LI M-C, 2013, J SCI EDUC TECHNOL	10.1007/s10956-013-9436-x	208	18.91	9.93

3	KIILI K, 2007, BR J EDUC TECHNOL	10.1111/j.1467-8535.2007.00704.x	207	12.18	3.03
4	YANG Y-TC, 2012, COMPUT EDUC	10.1016/j.compedu.2012.01.012	185	15.42	3.15
5	SHUTE VJ, 2016, COMPUT HUM BEHAV	10.1016/j.chb.2016.05.047	141	17.63	8.14
6	CORLETT J, 2000, NURSE EDUC TODAY	10.1054/nedt.1999.0414	134	5.58	2.36
7	FARASHAHI M, 2018, INT J MANAGE EDUC	10.1016/j.ijme.2018.01.003	97	16.17	12.02
8	KLEGERIS A, 2011, AM J PHYSIOL ADV PHYSIOL EDUC	10.1152/advan.00046.2011	93	7.15	4.35
9	ARGAW AS, 2017, EURASIA J MATH SCI TECHNOL EDUC	10.12973/eurasia.2017.00647a	88	12.57	5.65
10	PSYCHARIS S, 2017, INSTR SCI	10.1007/s11251-017-9421-5	83	11.86	5.33

Table 1 shows that the number of citations of more than half (60%) of the articles is above 120. This illustrates the importance of the topic discussed in the article and the extensive support from scientific literature regarding problem-solving skills [45], [46]. Furthermore, the development of research on problem-solving skills based on the number of citations from the 10 articles identified is shown in Figure 1 below.

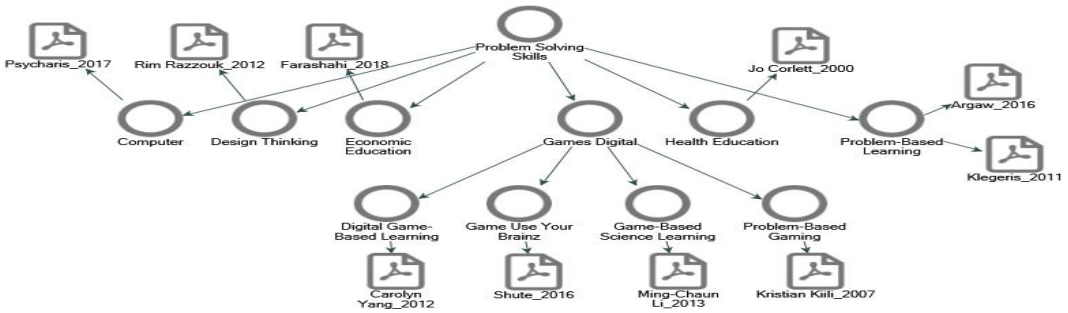


Figure 1. Development of Problem-Solving Skills

From Figure 1, it is identified that problem-solving skills in several studies are mostly related to games. This is in line with existing research, which consistently shows a positive relationship between games and problem-solving skills. Related research includes: strategy games and puzzles can significantly improve problem-solving skills, especially in analytical, logical, and creative thinking [47]. The PROSOLVE game was shown to improve problem-solving skills in novice programmers and was well-received by students and instructors [48]. High school students taking part in a summer game-design program showed significant increases in their problem-solving abilities, particularly in systems analysis and design and decision-making. These studies collectively highlight the potential of games as a tool for developing problem-solving skills.

3. Methods

The descriptive method was used in this research. Data were collected using documentation studies from the Scopus database and bibliometric analysis of academic articles related to problem-solving skills. This study used a bibliometric analysis strategy as its methodology. Using the R-Bibliometrix software during the performance analysis phase [49]. Five categories were used to quantify and summarize the findings of the fundamental analysis of research on problem-solving abilities: Annual Scientific Production, Most Relevant Sources, Most Prolific Authors, Most Cited Publications, and Most Relevant Keywords. The country cooperation network was created

during the science mapping step using the normalization of association strength [50]–[52], and was organized. Using VOSviewer, a bibliometric analysis program, this network was constructed [53]–[55], utilizing its clustering method even more [56], [57]. The bibliographic dataset was split into three primary research periods—the starting research era, the development research period, and the advanced research period—according to annual scientific production in order to examine research themes and their temporal history. Bibliometric made it possible to create a thematic map based on a network of often used words and their classifications for each time [49], [58].

Bibliometric analysis strategy

Data were extracted from Scopus (Core Collection) using keywords (themes) related to problem-solving abilities between August 2023 and 1981. The books, journals, conference proceedings, and book chapters that were found through the search were all fully annotated and referenced. There were two components to the data preparation phase. First, the depuration of the keyword data was done. To do this, every keyword associated with problem-solving abilities was used to create a de-pluralized corpus. Second, the data that appeared in each document were selected. The bibliometric analysis stages included activities of data collection, data analysis, and data visualization. Figure 2 illustrates the mapping workflow.

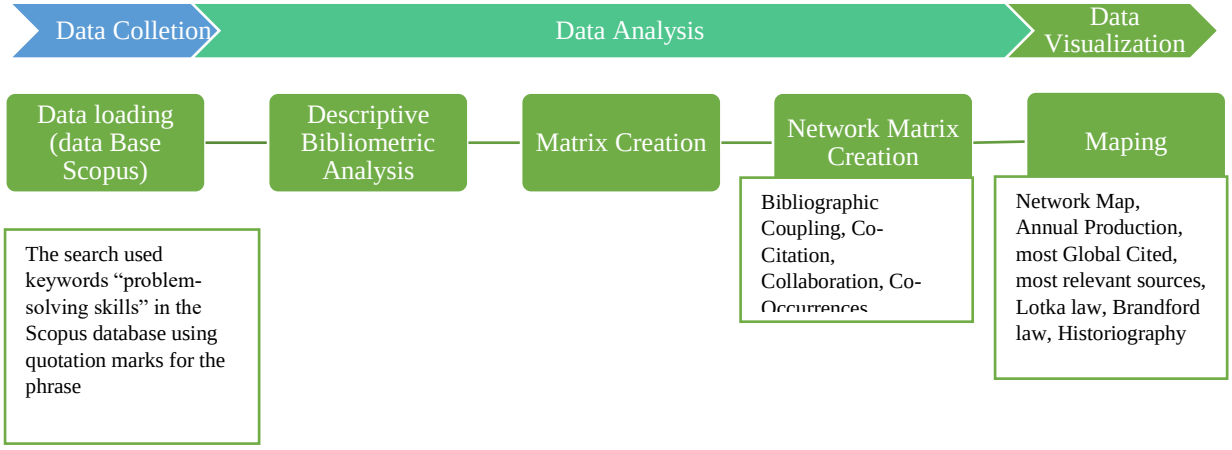


Figure 2. Bibliometric and science mapping workflow

4. Results and Discussion

The Impact of Publications on Problem-Solving Skills

The impact of publications in the realm of problem-solving was determined through citation analysis. K-indicators were employed in the citation analysis to gauge the effect and influence of publications according to their citation count [59]. An overview of the impact of publication on problem-solving skills over a period of 42 years (1981 – 2023) is summarized in Figure 3

.

Figure 3. Annual Information of Publications on Problem-Solving Skills

According to the Scopus database search strategy, 501 published articles or documents were obtained. These documents come from 245 different sources of scientific works (journals, books, etc.) from 1372 authors. 10.07 citations on average and 3.05 authors on average were found in each article. The annual growth rate of 14346 references was 8.76%. The average percentage change in a value or quantity from one year to the next is expressed

as the annual growth rate [60]. The rise in problem-solving skills publications was determined to be 8.76%. It was discovered that the writers of 501 papers utilized 909 keywords related to problem-solving abilities. The idea of K-indicators was first proposed by Wang and Chai in order to statistically characterize a scientific discipline's developmental stage [61], which is measured by the ratio between the number of keywords and documents. The K-indicator of scientific literature for problem-solving skills was 0.55. The K-indicator value is at the pre-normal science or normal science stage. This indicates that the current level of study on problem-solving skills is typical science, where the topic has developed over an extended period of time through the construction of a more developed notion. As shown by the mapping of Kuhn's scientific revolution paradigm, it is anticipated that research would advance to the next stage (post-normal) with greater scientific originality and vigor than previously [62], [63].

Annual Scientific Production

The annual scientific production shows in the 1981-2023 Scopus database, the highest number of publications on problem-solving skills occurred in 2019 (as shown in Figure 4). These findings correspond to advancements in specific scientific domains [64] during that time, including the emergence of many new findings, inventions, or advances in knowledge.

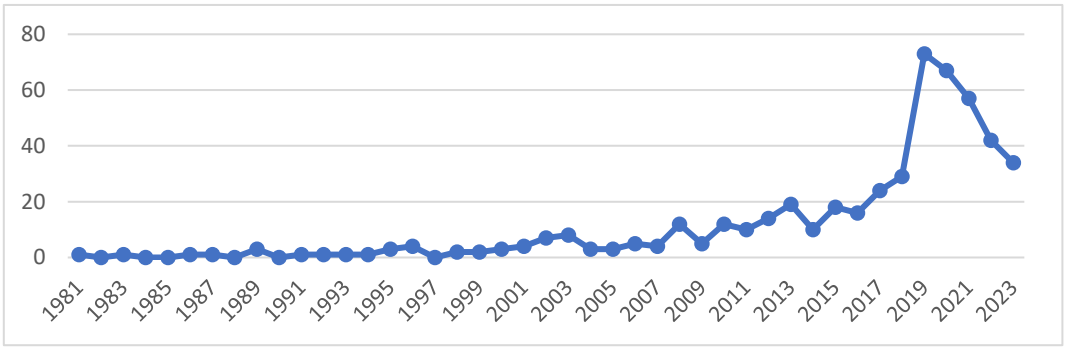


Figure 4. The Number of Publications on Problem-Solving Skills (1981-2023)

The number of publications increased significantly in 2019 because the topics discussed that year were more closely related to the readiness of the world of education in the era of the Industrial Revolution 4.0 in several aspects of the 21st-century skills that students need to master. The research intersects with problem-solving skills, which were the context and application of problem-based learning models [65], computer programming related to problem-solving skills and academic performance [66], and the application of project implementation to improve problem-solving skills [67]. The quantity of citations throughout a year will be discussed next. A crucial part of bibliometric analysis, which is a quantitative examination of scholarly and scientific literature, is citation analysis [68]. An article, book, or other scientific work's citation count serves as a gauge for how frequently it is cited in other scientific publications.

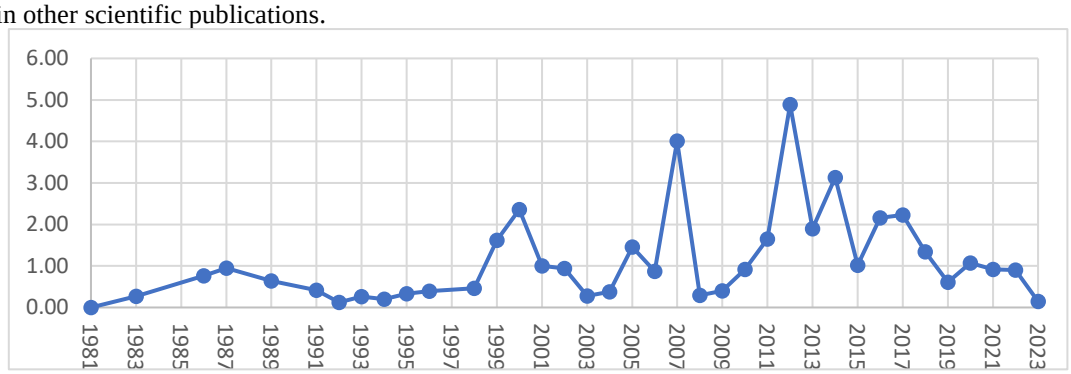


Figure 5. The Number of Citations of Problem-Solving Skills (1981-2023)

Regarding problem-solving skills, Figure 5 shows that 2012 was the year with the highest number of citations for the topic of problem-solving skills. The investigation identified the traits and attributes of design thinking as well

as its significance in enhancing students' capacity to solve problems in the twenty-first century [31] and the effects of digital game-based learning (DGBL) on students' academic performance, enthusiasm to study, and problem-solving skills [38].

Most Relevant Sources

In bibliometric analysis, the most significant and pertinent sources of information for the subject or research at hand are crucial [69]. To make it easier for writers to locate relevant material, Table 2 lists the top 10 sources that are pertinent to problem-solving skills.

Table 2. Ten Most Relevant Sources

Rank	Sources	Articles
1	Journal of Physics: Conference Series	84
2	AIP Conference Proceedings	31
3	Asee Annual Conference and Exposition, Conference Proceedings	19
4	Proceedings - Frontiers in Education Conference, Fie	11
5	Asee Annual Conference Proceedings	9
6	ACM International Conference Proceeding Series	7
7	International Journal of Instruction	7
8	Computers and Education	6
9	Jurnal Pendidikan IPA Indonesia	6
10	Computers in Human Behavior	5

Based on Table 2, discussions about problem-solving skills were mostly carried out in seminars and published in proceedings indexed by Scopus, followed by journals related to computer science, teaching, and Natural Sciences Education. Conference proceedings provide a platform for researchers to share ideas, discuss the latest research, and obtain feedback from fellow researchers [70]. Meanwhile, journals disseminate high-quality scientific information, facilitate knowledge exchange among researchers, and build a solid knowledge base [71]. Thus, it is necessary to increase publications in the form of journals related to problem-solving skills, so that we can continuously build knowledge in solving problems in learning.

The Next part discusses Bradford's Law. It was first introduced by Samuel C. Bradford in 1934. It is a concept in information science and bibliometrics that states that in a particular field, a small number of information sources (journals, authors, or subjects) will produce most of the relevant and important information [72]. Bradford's Law for Problem-Solving Skills is illustrated in Figure 6. It shows that the core zone in problem-solving skills is Journal of Physics: Conference Series, AIP Conference Proceedings, Asee Annual Conference and Exposition, Conference Proceedings, Proceedings - Frontiers in Education Conference, Fie, Asee Annual Conference Proceedings, ACM International Conference Proceedings Series, and International Journal of Instruction.

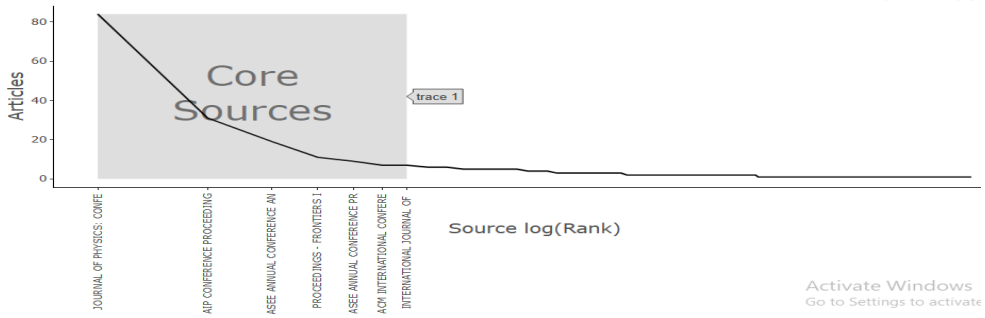


Figure 6. Bradford's Law for Problem-Solving Skills

Most Relevant Authors

The most relevant authors are crucial in identifying and assessing the caliber and significance of a scientific work in bibliometric analysis [73]. If an author has significantly influenced the work under analysis, then that author is deemed relevant. The writers listed below are the top ten in terms of problem-solving skills, as seen in Table 3.

Table 3. Ten Most Relevant Authors

Rank	Authors	Articles	Articles Fractionalized
1	Parno	7	1.73
2	Yuliati L	7	1.75
3	Ali M	5	1.06
4	Herayanti L	5	1.20
5	Gunawan G	4	0.95
6	Hermita N	4	0.55
7	Ikhsan M	4	1.33
8	Rahmani-Andebili M	4	4.00
9	Wati M	4	1.20
10	Zhang J	4	0.86

Table 3 shows that the majority of writers on problem-solving techniques are from Indonesia. Next, utilizing Lotka's Law methodology, the distribution of production across scientific authors was analyzed. According to Lotka's Law, there are roughly 10 times as many writers who produce one scientific work as there are authors who generate ten scientific articles, and so on [74], [75].

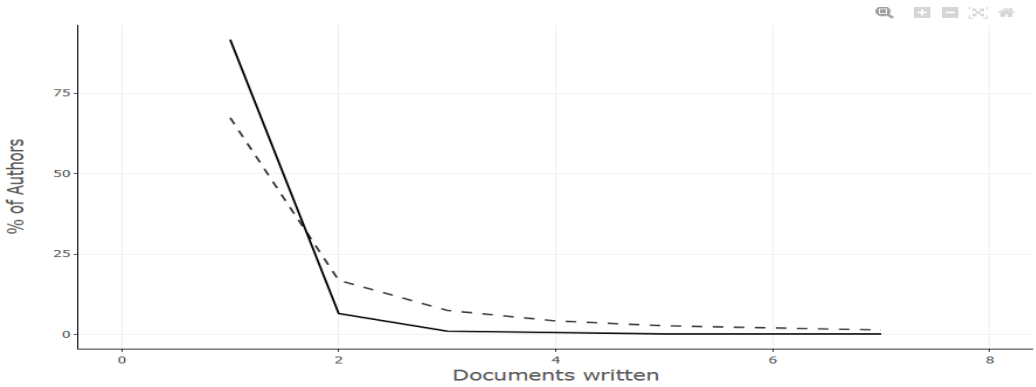


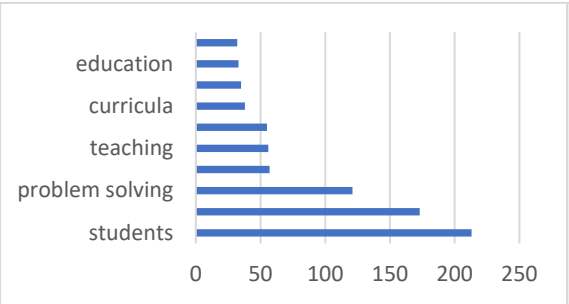
Figure 7. Lotka's Law for Problem-Solving Skills

In order to spread these ideas, it is necessary to increase the number of authors who can have an impact on the development of problem-solving skills by increasing publications in journals. As Figure 7 shows, only a small number of authors contributed significantly to research on problem-solving skills, and the majority of authors contributed with fewer works.

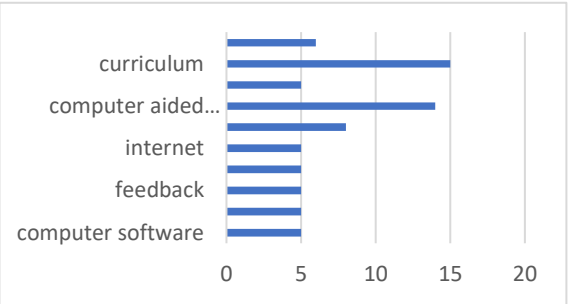
Most Relevant Keywords

Understanding the Most Relevant Keywords is crucial since they offer a concise and precise overview of the subject matter, emphasis, and pertinence of a group of scholarly articles [76]. As seen in Figure 8 below, the most Relevant Keywords appear as WordCloud, Trending Topics, and Most Frequent Words.

(a) Most Relevant Words



(b) Trend Topics



(c) WordCloud

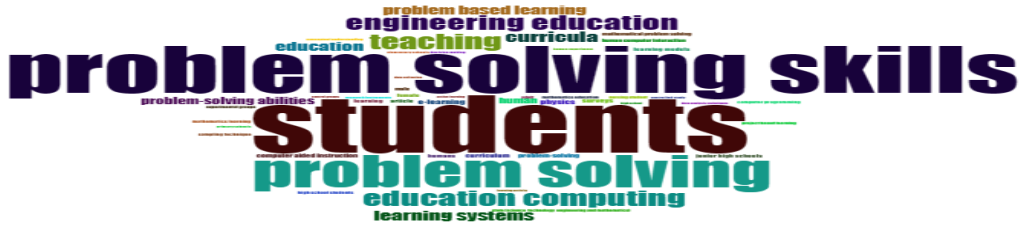


Figure 8. Most Relevant Keywords

Based on Figure 8, the most relevant keyword is 'student', while the most popular word is 'curriculum', and the word most often contained in articles is problem-solving skills. This shows that the discussion about problem-solving skills is oriented toward students and is related to the curriculum which contains problem-solving skills.

Country Collaboration Network

Collaboration networks between countries related to problem-solving skills were discovered using the VOSviewer. Collaboration networks between countries are displayed by VOSviewer according to the highest frequency. By default, the network was normalized using association strength [77], and it has been demonstrated that this mapping technique is among the greatest [51]. The weighting and variance parameters of the well-known modularity function of Newman and Girvan served as the foundation for the clustering algorithm [78]. The following is a network produced by VOSviewer

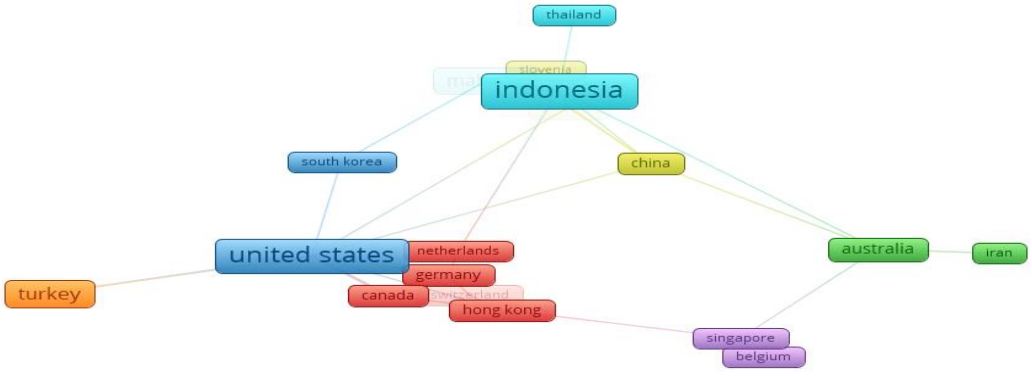


Figure 9. Country Collaboration Network

Based on the collected bibliographic data, Figure 9 depicts the cooperation network of the top 18 nations. The network illustrates the degree of communication amongst nations and nations with significant influence in this subject [79]. From the current network, seven major communities (each with a distinct color for a node) can be identified. Based on the quantity of publications, the size of the node indicates the influence of the nation in research on problem-solving abilities. The level of cooperative interactions between nations is reflected in the

connection between nodes. Indonesia and the USA are the most influential countries in this research, so other researchers in the field of problem-solving skills need to pay attention to the findings from these two countries. The following are the 10 countries with the most publications.

Table 4. Countries with the Most Publication Production

Rank	Region	Freq
1	Indonesia	556
2	USA	351
3	Turkey	90
4	Malaysia	73
5	China	66
6	Australia	28
7	Canada	20
8	South Korea	17
9	Germany	16
10	Iran	13

Indonesia having the largest number of publications is most likely because education in Indonesia is developing continually, and the government has recognized the importance of developing problem-solving skills in the education curriculum. Similar to Indonesia, education in America also emphasizes the importance of critical skills, including problem-solving skills.

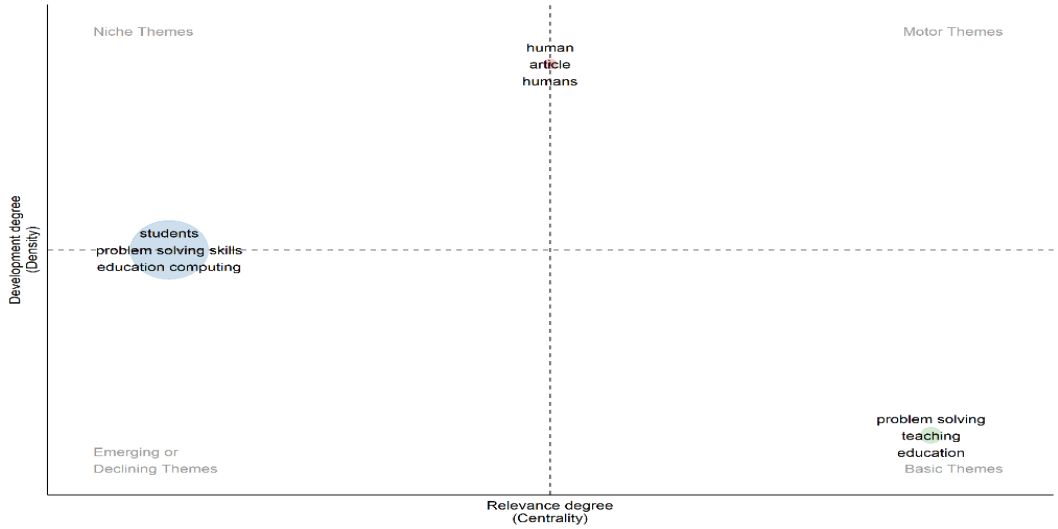
Thematic Analysis

Finding, evaluating, and reporting theme or motif patterns in qualitative data is done using the analytical technique known as thematic analysis [80], [81]. This approach is crucial to the study of bibliometrics, which quantifies and examines the volume, distribution, and impact of published scientific literature.

The Thematic Map, which is divided into four quadrants, displays the thematic pattern. The motor theme space is located in the first quadrant (Central and developing); the basic and transversal theme space is located in the second quadrant (Central and undeveloped); the highly developed and isolated theme space is located in the third quadrant (Peripheral and developed); and the space for themes that emerge or decline is located in the fourth quadrant (Peripheral and not developing) [82].

A thematic map of articles on problem-solving skills shown in Figure 10. Every circle is a cluster, and the size of the circle (the total number of phrases or keywords) reflects the size of the cluster. Scholars have also provided a more comprehensible interpretation of these diagrams [58]. Problem-solving has been the primary focus for 42 years (1981–2023) and is still relevant to contemporary developments, as shown by the Thematic Map (in Figure 10). For this reason, it is vital to reinforce the educational process that takes this into consideration. The ability to solve problems is crucial in the modern period of progress. Given the dynamic nature of contemporary society and the phenomenon of globalization, problem-solving abilities are highly esteemed not only in the realm of academia but also in the professional and personal spheres.

To strengthen the thematic map, it is necessary to pay attention to factor analysis in a bibliometric context. This was used to identify the main factors that influence co-citation patterns or citation patterns in literature data sets. Figure 11 illustrates the factor analysis.



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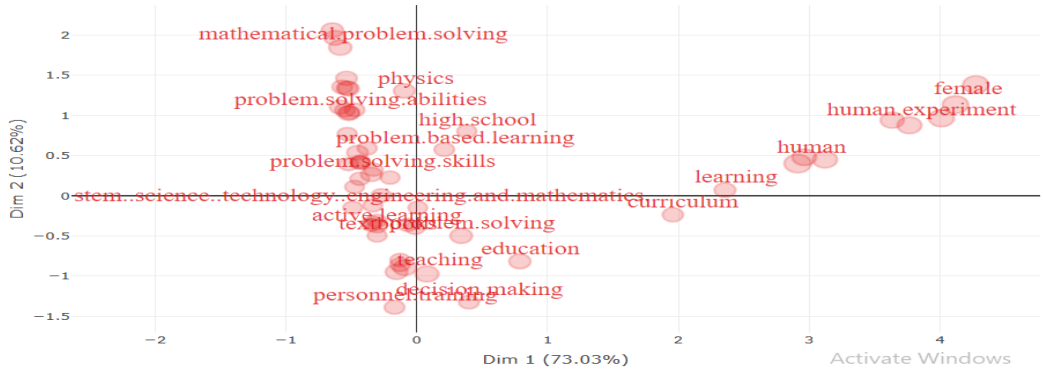

Figure 11. Factorial Analysis

Figure 11 shows that problem-solving and problem-solving skills are approaching the center point, so it can be concluded that these two topics are the main topics as explained in the thematic map.

5. Conclusions

From the development of research related to problem-solving for 42 years (1981-2023), it was discovered that the K-indicator value is at the pre-normal science or normal science stage, thus research on problem-solving skills is currently at the normal science stage. The highest number of publications was in 2019. Meanwhile, the highest number of citations occurred in 2012. Discussions related to problem-solving were mostly in seminars and published in proceedings indexed by Scopus, then in journals of computer science, teaching, and Natural Sciences Education. Indonesia is the country of origin of most writers on problem-solving skills. Only a few authors have had a big impact on research on problem-solving skills and most authors contribute with a smaller number of works; hence, it is necessary to increase the number of authors who can have an impact on the development of problem-solving skills by increasing publications in the form of journals to disseminate the ideas. ‘Student’ is the most relevant word, while ‘curriculum’ is the most popular word, and the word/phrase most often contained in articles is ‘problem-solving skills.’

The USA and Indonesia are the two nations that have had the greatest influence on problem-solving skills research, thus other academics studying this topic should take note of what these two nations have to say. It is vital to reinforce the teaching methodology that takes this into consideration because problem-solving is still a major

subject and is pertinent to contemporary advancements. The findings of the component analysis indicated that problem-solving and problem-solving skills are at the center, indicating that these two subjects are the primary subjects.

In the context of globalization and a society that is always evolving, problem-solving skills are necessary not just in the workplace and in everyday life, but also in the educational setting. The findings of this study will be helpful in determining future research paths and research interests related to the problem-solving skills of students. They will also serve as a strong foundation for future research..

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