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# Bibliometric Analysis of Research on Project-Based Learning Model with STEM Approach in Mathematics Education

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**ABSTRACT**

This study investigated the development of research on Project-Based Learning model with STEM approach in Mathematics Education through a bibliometric computational mapping analysis using VOSviewer. Publish or perish was used to get the article data from Google Scholar. The search process was guided by the article title and abstract, which referred to the keyword "Project-Based Learning Model with STEM approach in Mathematics Education". A total of 41 papers were considered relevant. The research period of the paper used was from the past 10 years (2014 to 2023) indexed by Google Scholar. The research results showed that the Project-Based Learning model with STEM approach in mathematics education research could be divided into three terms. The first term was teaching method in cluster 4 with 18 total links, 19 total link strengths, and 12 occurrences. The second term was STEM learning, included in cluster 6 with 15 full links, 15 total link strength, and 11 occurrences. The third term was STEM PjBL, included in cluster 8 with 13 total links, 15 total link strength, and 10 occurrences. The analysis results of the development of the Project-Based Learning model with STEM approach publications in mathematics education in the last ten years showed frequent fluctuations. From 2014 to 2016, publications increased at the same rate in 2016 and 2017 and decreased in 2018. It then increased again in 2019 to 2020 but decreased in 2021 and 2022. Until, in 2023, it rose again. The number of publications in 2023 could continue to grow because the data were taken in the middle of 2023. The result of the study shows that research opportunities for the Project-Based Learning model with the STEM approach, especially in mathematics education, still have high options and are related to other terms.

***Keywords:***
Bibliometric analysis; mathematics education; project-based learning; STEM approach; VOSviewer

## 1. Introduction

One area of education that is continuously developing is mathematics education. In 2018, the Minister of Education and Culture of the Republic of Indonesia stipulated regulation number 35, stating that mathematics aims to develop student attitudes, knowledge, and technical skills as the foundation to enhance their life skills. Mathematics must be learned in order that students have various capabilities, such as mathematical problem-solving, mathematical communication,

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mathematical reasoning and proof, mathematical connections, and mathematical representation [1]. For mastering various mathematical abilities, teachers must apply different strategies, methods, and learning models suitable for application in mathematics learning.

One learning model considered suitable for mathematics is Project-Based Learning (PjBL) model with a Science, Technology, Engineering, and Mathematics (STEM) approach. STEM is one of the important approaches for supporting education [2,3].

PjBL model is a learning model considered relevant for learning in the 21st century. Many reports on PjBL are available [4-10]. One of the advantages of the PjBL model is that the problems presented in the PjBL model are problems originating from everyday life. Thus, PjBL not only equips students with knowledge but also improves the student ability to solve problems in their lives [11]. In addition, the PjBL model provides opportunities for students to be involved both individually or in groups in formulating questions, setting goals, planning, up to implementing and designing projects [12] because it is not like traditional learning which makes the teacher the primary source of information and dominate the time [13] The PjBL model makes students play an active role and dominate the learning process. Another advantage of PjBL model is that it provides opportunities for students to assess themselves based on the produced products. Besides that, they can also evaluate work or projects done by their friends and provide constructive suggestions. This can help students realize the strengths and abilities they must continue to improve [14].

In line with the PjBL model, the STEM approach uses real-world contexts as the center of education because the STEM approach has the goal of preparing individuals to face complex real-world problems and requires the application of knowledge and skills from various disciplines [15]. The STEM approach is also recommended for improving and developing student problem-solving skills [16]. However, the demand for research on mathematics education related to Project-Based Learning models using STEM approaches is still under investigation. Mathematics education research has used analytical methods that enable the development of Project-Based Learning models with STEM approach, such as bibliographic analysis. Bibliographic analysis is a type of research using data meta-analysis that helps researchers examine bibliographic content and analyze citations from journal articles and other scholarly studies.

There are many studies utilizing bibliographic analysis, including bibliographic that analysis in mathematics education [17-24], economics [25-28], engineering [29-34], technology [35-36], e-learning [37-41], covid-19 [42], renewable energy [43], artificial intelligence [44], mobile learning [45], infectious diseases [46], and many more (see Table 1).

**Table 1**
Previous studies on bibliometric analysis

| Authors | Title | Results | Ref |
|---|---|---|---|
| Muhammad *et al.,* | Discovery learning research in mathematics learning: a bibliometric review | In 2017 – 2023 the publication of discovery learning in mathematics education was increased. Indonesia became a country that had a big influence on it. The focus of this research consisted of 1) students, mathematics learning, and discovery learning, 2) Indonesia and problem-solving, and 3) geometry and junior high school. | [17] |
| Muhammad & Angraini | Research on students' mathematical ability in learning mathematics in the last decade: a bibliometric review | The trend of publications on mathematics skills in learning mathematics increased in 2018 - 2019. However, the highest number of citations occurred in 2013, it was 612 citations. The focus of this field included 1) ICT, university, computational thinking, and augmented reality, 2) higher education, pre-service teachers, and mathematical problems, 3) outcomes, mathematics literacy, and mathematics abilities, and 4) | [18] |

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|---|---|---|---|
| | | technology, high mathematical ability, and critical thinking ability. | |
| Muhammad *et al.,* | Bibliometric analysis: Adobe Flash C26 research in mathematics learning | The most citations of publications related to Adobe Flash in mathematics learning occurred in 2018. There were more than 150 citations, while the most publications for this research occurred in 2019. The focus of this research could be grouped into 1) interests, motivations, and problems, 2) elementary school, contextual teaching, and development, 3) technology and outcomes. | [19] |
| Sugiarni *et al.,* | Research trends mathematics concepts on pre-service mathematics teachers: a bibliometric analysis using Vosviewer from 2017 to 2022 | From 2017 until 2022, the publication of pre-service mathematics teachers on the Scopus database produced 118 documents with a total of 337 citations. The keywords that often appeared in this research were professional development, concept map, teacher knowledge, mathematics content, and STEM education. | [20] |
| Naser & Juandi | Bibliometric review: research on mathematical literacy ability in mathematics learning (1979-2023) | Based on data from the Scopus database, the most publications related to mathematical literacy in mathematics learning occurred in 2022, while the most citations occurred in 2015. There were 295 citations. Southern Africa was the country that had the greatest influence regarding publications in this field with a total of 26 publications. The focus of this research included mathematics education, students, numeracy skills, and gender. | [21] |
| Kaymak *et al.,* | A bibliometric review on realistic mathematics education database between 2000-2022 | The countries that had the most research related to Realistic Mathematics Education were Indonesia, the Netherlands, and the United States. Most publications came from Indonesia, but the citations about RME were more often from the Netherlands. RME was still widely explored and used in technology-based learning so researchers believed that the number of publications on this topic would continue to increase. | [22] |
| Phan *et al.,* | A bibliometric review on realistic mathematics education in Scopus database between 1972-2019 | Research in the field of Realistic Mathematics Education (RME) had increased, especially after 2016. The Netherlands was the country with the most cited publications in the field of RME. But, if measured by total publications, Indonesia produced the most publications in the field of RME. | [23] |
| Dede & Ozdemir | Mapping and performance evaluation of mathematics education research in Turkey: a bibliometric analysis from 2005 to 2021 | Publications related to Mathematics Education Research in Turkey increased slowly until 2012 but then declined and experienced fluctuations. The topics most widely discussed were mathematical modelling, mathematical achievement, and attitudes. Meanwhile, topics that needed further research were anxiety in mathematics education, gender, problem-based learning, spatial abilities, functions, and proportional reasoning. | [24] |
| Suseelan *et al.,* | Research on mathematics problem solving in elementary education conducted from 1969 to 2021: a bibliometric review | The United States was the most productive country in the field of mathematics problem-solving publications, especially in Elementary Education. The focuses of the research were 1) mathematical problem-solving and representation, 2) mathematical problem-solving in the affective domain, 3) student cognition, 4) essay questions, 5) role of teachers in problem-solving, 6) problem-solving in algebra. | [25] |
| Lada *et al.,* | Islamic economy and sustainability: a bibliometric analysis using R | From 2000 to 2022 there were 76 publications relevant to the topic of Islamic Economy and Sustainability. To produce new research related to this topic, the author provided suggestions for condensing important aspects of Islamic economics into one integrated concept so that it would become a trending research topic for discussion. | [26] |

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| Zeng & Yang | A bibliometric and visualization analysis of knowledge mapping in digital economy research, 1992–2022 | There were a lot of research in the field of digital economy proven by the large number of publications. Based on the SSCI and SCI databases, from 1992 to 2022, there were 7874 published articles. Related research that had the potential to be carried out was digital economic platforms, the gig economy, big data technology innovation, and digital economic statistics. | [27] |
| Duan | A state-of-the-art review of sharing economy business models and a forecast of future research directions for sustainable development: a bibliometric analysis approach | Analysis of the Scopus and Web of Science databases showed that there were 951 studies from 552 sources identified. Sustainability was the most relevant journal and one of the most influential in the field of Sharing Economy Business Models (SEBM). | [28] |
| Zhong & Lin | Bibliometric analysis for economy in covid-19 pandemic | A search using the keywords economy, economic, and financial from 2020 to 2022 produced 2274 related documents. North America and Europe were the most productive countries in producing publications in this field, while the most popular journal was Sustainability. | [29] |
| Zhou *et al.,* | The low-carbon transition of energy systems: a bibliometric review from an engineering management perspective | Over the last decade, the number of publications in this field had experienced rapid growth. Based on 5336 publications analyzed, most of the authors came from China, Germany, England, the United States, and the Netherlands. There were four main research themes, namely low-carbon technology diffusion, low-carbon transition pathway, transition-driving mechanisms, and infrastructure network planning. | [30] |
| Duan *et al.,* | Development and research trends of a polypropylene material in electrical engineering: A bibliometric mapping analysis and systematical review | The country that published the most research related to polypropylene (PP) in the field of electrical engineering was China, but the most cited publication came from the United States. Most of the articles were published in dielectric and materials journals. The most popular research in this field was related to electricity, mechanical properties, and nanomodification. | [31] |
| Al Husaeni & Nandiyanto | Bibliometric computational mapping analysis of publications on mechanical engineering education using Vosviewer | Publications on mechanical engineering education from 2012 to 2021 experienced quite frequent fluctuations and were most popular in 2012 with 56 publications. This research related to 157 links divided into 3 terms, including mechanical engineering, mechanical engineering education, and education. | [32] |
| Wirzal & Putra | What is the correlation between chemical engineering and special needs education from the perspective of bibliometric analysis using Vosviewer indexed by Google Scholar | Based on the keywords chemical engineering and special needs, there were 800 relevant articles published from 2018 to 2022. The number of publications in this field decreased from year to year because of the Covid-19 pandemic. | [33] |
| Nandiyanto & Al Husaeni | Bibliometric analysis of engineering research using Vosviewer indexed by Google Scholar | There were 1000 relevant articles published from 2017 to 2021. In the last 5 years, engineering research had decreased. In 2017, there were 396 articles, but the number of articles dropped drastically to just 14 articles in 2021. The most researched term in this field was engineering, while the least researched term was environment. | [34] |

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| Sudrajat *et al.,* | Engineering design process: a review and bibliometric analysis | There were 999 articles published from 2016 to 2021. Then, all of these articles were analyzed. There were 762 articles relevant to the engineering design process topic. The clusters formed in this research were related to various keywords. | [35] |
| Radanliev & Roure | New and emerging forms of data and technologies: literature and bibliometric review | The strong relationship between the US and the UK did not suggest collaborative research on this topic. The opposite happened to the US and China, even though the relation between the two countries were not good. Research on this topic seemed to be getting stronger. | [36] |
| Jeflea *et al.,* | Societal technological megatrends: a bibliometric analysis from 1982 to 2021 | Analysis of 549 articles from Scopus and 291 articles from Web of Science (WoS) showed that the publication of technology megatrends started in 1982 and showed an increasing trend after 2010. At the societal level, technological megatrends were closely related to foresight, industry 4.0, globalization, digitalization, the Internet of Things, technology, innovation, and artificial intelligence. | [37] |
| Djeki *et al.,* | E-learning bibliometric analysis from 2015 to 2020 | Based on a study of 12,272 publications published from 2015 to 2020, it concluded that China, the USA, England, and Spain were the most productive countries in research on e-learning. The most influential writer in this field was A. Tarhini. Journal of Emerging Technologies in Learning was the most represented journal. Meanwhile, the universities that had the most influence were Universidade Nova de Lisboa, Islamic Azad University, and King Abdulaziz University. | [38] |
| Fauzi | E-learning in higher education institutions during COVID-19 pandemic: current and future trends through bibliometric analysis | A study of 1496 publications provided an illustration that research related to e-learning during COVID-19 was carried out over a two-year period (2019 – 2020). E-learning should be carried out in universities so that student rights to obtain education could be fulfilled. | [39] |
| Martins *et al.,* | A bibliometric analysis and visualization of e-learning adoption using vOSviewer | The results of the analysis of 896 articles published from 1989 to 2021 showed that Indonesia and Malaysia were countries that paid a great attention to e-learning adoption. The institutions that published the most were universities from Indonesia and Malaysia. The countries that cited the most publications related to e-learning adoption were Spain, Taiwan, Malaysia, the USA, and the UK. Meanwhile, the journal that had the most publications on this topic was Elsevier. | [40] |
| Fan *et al.,* | Bibliometric analysis on Covid-19: a comparison of research between English and Chinese studies | Since Covid-19 appeared, publications related to Covid-19 had grown rapidly. A total of 721 Chinese language articles had been published, beating the number of English language articles which were only 143 articles. Publications in English involved doctors and scientists at the international level. | [41] |
| Rosokhata, *et al.,* | Renewable energy: a bibliometric analysis | A search for the keyword renewable energy yielded 17,805 publications. About 51.7% of the publications were published from 2016 to 2020. The most popular research topics in this field were engineering, energy fuels, environmental sciences, science and technology, ecology, and business economics. | [42] |
| Bawack *et al.,* | Artificial Intelligence in e-Commerce: a bibliometric study and literature review | Based on the analysis of 4335 publications, it concluded that the USA and China were the leaders in this research area. The thing most researched was recommender systems with the themes of AI concepts, trust and personalization, optimization, sentiment analysis, and related technologies. | [43] |
| Goksu | Bibliometric mapping of mobile learning | The countries that were most effective in mobile learning were China, USA, Taiwan, and England. The most dominant keyword of research in this field was educational technologies which could | [44] |

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| | be more specifically described as mobile phones, tablets, MOOCs, and learning strategies. The most effective research in this area included smartphone-oriented, augmented reality, and higher education. Meanwhile, the journals that contributed the most were the Computers & Education Journal, the British Journal of Educational Technology, and the Educational Technology & Society Journal. |

However, computational mapping research using bibliometric analysis of data published related to the Project-Based Learning model with STEM approach in mathematics education research to discover the research development has not been widely carried out, specifically the bibliometric analysis of the last ten-year research from 2014 to 2023 utilizing the VOSviewer application. This study was therefore conducted to perform a bibliographic computational mapping analysis of papers indexed by Google Scholar using the VOSviewer software. This research was conducted to help researchers orient and set research themes, especially in the context of Project-Based Learning model with STEM approach in mathematics education.

## 2. Methodology

The data used in this study were based on articles published in peer-reviewed journals indexed by Google Scholar. We chose Google Scholar for this research because the Google Scholar database is open source [46]. A reference manager application, such as Publish or Perish, was used for literature searches on selected topics. For more details on the use and installation of the software and the step-by-step data acquisition process, please refer to the previous study [47]. This research was conducted in several stages, including:

(i) Using the Publish-or-Perish application to collect and choose the publication data,
(ii) Opening the Microsoft Excel application to do the bibliographic data process,
(iii) Opening the VOSviewer application to do a computer-aided mapping analysis of biometric publication data,
(iv) Analyzing the computational mapping results after the results appeared in the VOSviewer application.

All data in this document was collected in June 2023. The collected data that met the criteria for this research analysis were exported into two types of files, namely comma-separated value format (*.csv) and Research Information System (.ris). VOSviewer also allows us to visualize and assess trends using bibliographic maps. Then, the item data from the source database were mapped.

VOSviewer creates three variants of mapping publications, including density visualization, network visualization, and network-based overlay visualization (co-citation) between existing elements. When creating the bibliographic map, the keyword frequencies were adjusted to find the keywords at least thrice. As a result, 137 irrelevant terms and keywords were removed. Figure 1 shows the research stage.

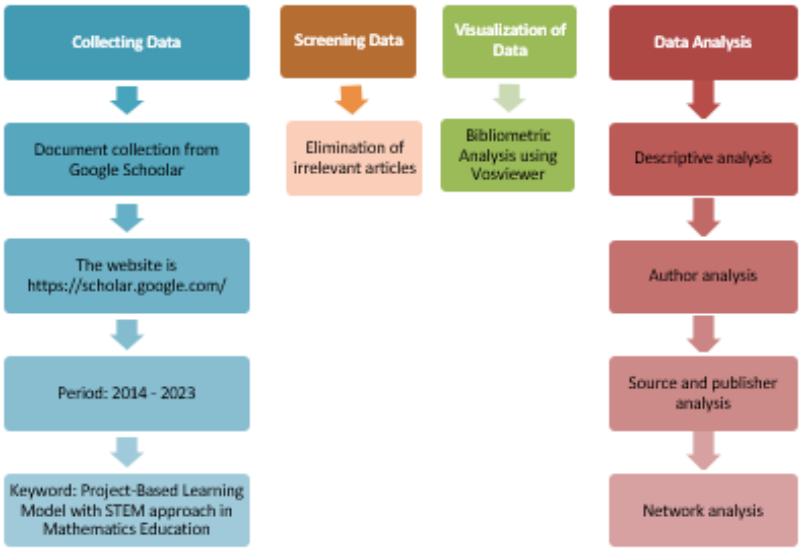


**Fig. 1.** Research procedure

## 3. Results

### *3.1 Publication Data Search Results*

The data search through published or perish reference management applications from the Google Scholar database yielded 41 articles that met the research criteria. The data retrieved were in the form of written metadata consisting of the title of the paper, year of publication, number of citations, journal name, publisher, author name, article link, and associated URL. Table 2 shows examples of published data used in VOSviewer analysis for this study. The top 20 most cited papers about the PjBL Model with STEM approach in Mathematics Education were used as sample data. All papers used in this study had 1731 citations, with an annual citation count of 173.1. The number of citations per article was 14.41 and the average author of articles was 2.93.

The most cited article was an article published in 2014 [48]. This article received many citations because, in 2014, this article was the only article that discussed how PjBL STEM influenced achievement of students who had different abilities (high, medium, and low). The authors explained their research well, starting with an explanation of student achievement influenced by individual factors (student factors) and learning environment factors (which were raised in this research, namely PjBL STEM). The number of citations to this article was increasing day by day, starting from researchers who only focused their research on PjBL, researchers who only focused on STEM, or researchers who combined PjBL and STEM, both in mathematics learning and non-mathematics learning.

On the other hand, six articles had never been cited. These six articles were published in 2023. The publication year of these six articles was the same as the year in which the data were collected and analyzed, so these six articles still had the possibility of being cited in the month or year after the data were collected.

**Table 2**
PjBL model with STEM approach in mathematics education publication data

| No | Authors | Title | Year | Cites |
|---|---|---|---|---|
| 1 | Han *et al.,* [48] | How Science, Technology, Engineering, and Mathematics (STEM) Project-Based Learning Affects High, Middle, and Low Achievers Differently: The Impact of Student Factors on Achievement | 2014 | 690 |
| 2 | Ismayani [49] | Pengaruh Penerapan STEM Project-Based Learning terhadap Kreativitas Matematis Siswa SMK | 2016 | 213 |
| 3 | Han *et al.,* [50] | The Effect of Science, Technology, Engineering, and Mathematics (STEM) Project-Based Learning on Students' Achievement in Four Mathematics Topics | 2016 | 136 |
| 4 | Cinar *et al.,* [114] | Views of Science and Mathematics Pre-service Teachers Regarding STEM | 2016 | 100 |
| 5 | Bicer *et al*., [115] | STEM Schools Vs. Non-STEM Schools: Comparing Students' Mathematics Growth Rate on High-Stakes Test Performance | 2015 | 75 |
| 6 | Hadiyati *et al.,* [116] | Development of Mathematics E-Module with STEM-Collaborative Project-Based Learning (PjBL) to Improve Mathematical Literacy Ability of Vocational High School Students | 2021 | 54 |
| 7 | Lee *et al.,* [117] | Affective Mathematics Engagement: a Comparison of STEM PBL Versus Non-STEM PBL Instruction | 2019 | 48 |
| 8 | Widana and Septiari [118] | Kemampuan Berpikir Kreatif dan Hasil Belajar Matematika Siswa Menggunakan Model Pembelajaran Project-Based Learning Berbasis Pendekatan STEM | 2021 | 46 |
| 9 | Priatna *et al.,* [119] | STEM Education at Junior High School Mathematics Course for Improving the Mathematical Critical Thinking Skills | 2020 | 37 |
| 10 | Octaviyani *et al.,* [120] | Peningkatan Kemampuan Berpikir Kreatif Matematis Siswa melalui Model Project-Based Learning dengan Pendekatan STEM | 2020 | 35 |
| 11 | Viro *et al.,* [121] | Teachers' Perspectives on Project-Based Learning in Mathematics and Science | 2020 | 35 |
| 12 | Jacques [122] | What does Project-Based Learning (PBL) Look Like in The Mathematics Classroom? | 2017 | 33 |
| 13 | Craft and Capraro [123] | Science, Technology, Engineering, and Mathematics Project-Based Learning: Merging Rigor and Relevance to Increase Student Engagement | 2017 | 33 |
| 14 | Capraro and Nite [124] | STEM Integration in Mathematics Standards | 2014 | 30 |
| 15 | Bowen and Peterson [125] | Exploring Authenticity Through an Engineering-Based Context in a Project-Based Learning Mathematics Activity | 2019 | 24 |
| 16 | Luneeva and Zakirova [126] | Integration of Mathematical and Natural Science Knowledge in School Students' Project-Based Activity | 2017 | 24 |
| 17 | Chalim *et al.,* [127] | Kemampuan Komunikasi Matematis Siswa SMK Ditinjau dari Self Efficacy pada Setting Pembelajaran Project Based Learning Terintegrasi STEM | 2019 | 19 |
| 18 | Anindayati and Wahyudi [128] | Kajian Pendekatan Pembelajaran STEM dengan Model PjBL dalam Mengasah Kemampuan Berpikir Kreatif Matematis Siswa | 2020 | 15 |
| 19 | Evans *et al.,* [129] | Math Path: Encouraging Female Students in Mathematics through Project-Based Learning | 2018 | 12 |
| 20 | Hakim *et al.,* [130] | STEM Project-Based Learning Models in Learning Mathematics to Develop 21$^{st}$-Century Skills | 2018 | 9 |

### *3.2 Research Development in the Field of PjBL Model with STEM Approach in Mathematics Education*

Table 3 and Figure 2 show the development of the Project-Based Learning model using the STEM approach in mathematics education research published in peer-reviewed journals indexed by Google Scholar. Based on the data presented in Table 2, we found that the number of Project-Based Learning models using the STEM approach in mathematics education research was 41 papers from 2014-2023. There was one article in 2014, two in 2015, five in 2016, and five in 2017. In 2018, the number of

published articles decreased sharply to just one. This decline occurred because, in 2018, people were not familiar with the Project-Based Learning model combined with STEM in mathematics. At that time, researchers mostly used other models or approaches. One of the approaches chosen was Realistic Mathematics Education (RME). If we use the keyword RME in mathematics in the Google Scholar search engine, we will find approximately 2550 results. Many researchers took this theme because they believed RME could help students be active in learning mathematics [50].

In 2019 and 2020 the number of articles increased. This happened because, at that time, Covid-19 occurred which caused the learning mode to change from offline to online, so it involved a lot of technology in learning. Also, the learning system directed students to work on projects and of course it required a Project-Based Learning model using the STEM approach in mathematics education. The number of articles decreased again in 2021 and 2022. This decline did not last long because the number of articles increased in 2023. Based on the analysis carried out, it concludes that the popularity of Project-Based Learning model research with a STEM approach in mathematics education tends to fluctuate. However, in 2023, interest in this research would likely increase again. In mid-2023, the number of articles published had reached 6 articles and would probably increase even more until the end of 2023.

**Table 3**
Development of PjBL model with STEM approach in mathematics education research

| Year of paper publications | Number of publications each year |
|---|---|
| 2014 | 1 |
| 2015 | 2 |
| 2016 | 5 |
| 2017 | 5 |
| 2018 | 1 |
| 2019 | 5 |
| 2020 | 7 |
| 2021 | 5 |
| 2022 | 4 |
| 2023 | 6 |
| Total | 41 |
| Average per Year | 4.1 |

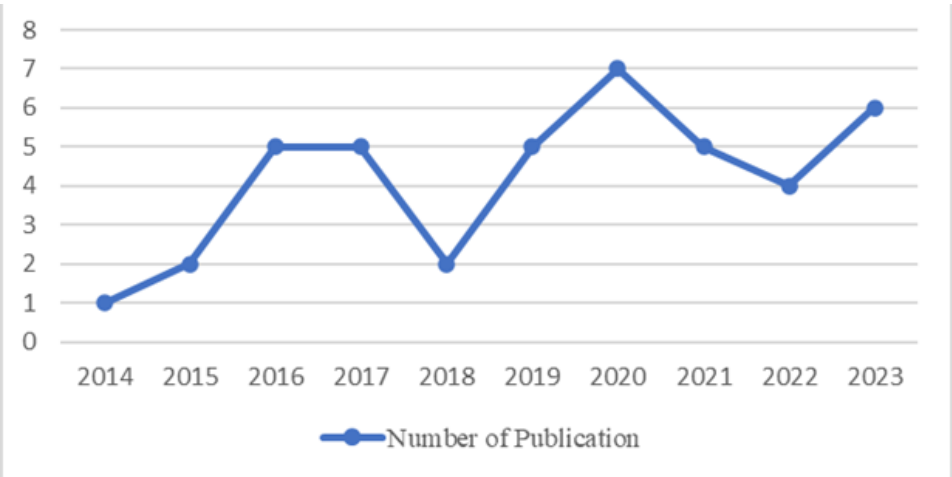


**Fig. 2.** Level of development of the PjBL model with STEM approach in mathematics education research

### *3.3 Publication Data Search Results*

The application used in this research was VOSviewer because this application is usually used to do computational mapping. The arithmetic assignment resulted in 106 elements. Each element in the data mapping associated with PjBL model using STEM approach to mathematics education research was divided into the following ten clusters.

(i) Cluster 1 contained 14 elements marked in red. The 14 elements were higher-order thinking skill, innovation, junior high school, learning activity, learning approach, PjBL learning model, primary school, science learning, scientific approach, STEM education program, STEM integration, STEM literacy, STEM teaching, and teaching model.

(ii) Cluster 2 contained 14 elements marked in green. The 14 elements were based on learning, challenge, experience, innovative approach, inquiry learning, learner, lesson, modeling, PBL approach, pedagogical approach, progress, scientific reasoning, STEM discipline, and STEM program.

(iii) Cluster 3 contained 14 elements marked in blue. The 14 elements were creative thinking, creative thinking skill, elementary school, evaluation, integrated approach, integrated STEM education, interdisciplinary approach, interdisciplinary project, mathematical modeling, PjBL STEM, research method, student worksheet, and technique.

(iv) Cluster 4 contained 12 elements marked in yellow. The 12 elements were high school, influence, mathematics teacher, models, motivation, relationship, self-efficacy, STEM career, STEM school, STEM student, student achievement, and teaching method.

(v) Cluster 5 contained 11 elements marked in purple. The 11 elements were authentic project, contribution, educational technology, effective approach, Geogebra, math education, mathematics classroom, reality, researcher, standard, and student learning.

(vi) Cluster 6 contained 10 elements marked in sky blue. The 10 elements were 21$^{st}$ century, content, integrated STEM, learning method, pedagogical method, science subject, STEAM, STEM curriculum, STEM learning, and students' creativity.

(vii) Cluster 7 contained 10 elements marked orange. The 10 elements were behavior, class, discovery, improvement, learning process, model project, skills, STEAM project, stem integrated project, and teacher education.

(viii) Cluster 8 contained 8 elements marked in brown. The 8 elements were alternative approach, instructional method, mathematics project, STEM PBL, STEM PjBL, students' attitude, subject, and teaching material.

(ix) Cluster 9 contained 3 elements marked pink. The 3 elements were middle school, STEM education project, and teaching science.

(x) Cluster 10 contained 3 elements marked in coral pink. The 3 elements were practice, stem environment, and STEM subject.

The relationship between a term and another term is displayed in each existing cluster. Each term is marked with a colored circle. The size of the circle for each strain varies according to the frequency of occurrence of that strain [51]. The size of the circle label positively correlates with term occurrence in titles and abstracts [52]. The more frequently a term occurred, the larger the size of the label [48]. The mapping visualization analyzed in this study consisted of three parts, namely network visualization, density visualization, and overlay visualization [53].

Figure 3 shows a network visualization describing the relationship between terms. The relationships between concepts were described in a coherent network. Figure 3 shows clusters of terms commonly explored related to the Project-Based learning model research topic using STEM

approach in mathematics education. The clusters in the network visualization showed that the Project-Based Learning model with the STEM approach in mathematics education could be divided into three areas. The first area was the teaching method. It had 18 total links, which were included in cluster 4. The total link connection strength was 19 and the number of occurrences was 12. Teaching method had a network with other terms, including integrated project, student worksheet, influence, student achievement, high school, mathematics teacher, STEM student, self-efficacy, STEM education program, learning activity, teaching model, 21st century, scientific reasoning, progress, disciplinary stem, PjBL STEM, researcher, and standard. The second area was STEM learning contained in cluster 6 with 15 total links, 15 total link strengths, and 11 occurrences. STEM learning had a network with other terms, including STEM, students' creativity, science subject, practice, science learning, PjBL learning model, primary school, higher order thinking skill, experience, teaching material, mathematics project, subject, contribution, and teaching science. The third area was STEM PjBL. It was in cluster 8 with 13 total links, 15 total link strengths, and 10 occurrences. STEM PjBL had a network with other terms, including skills, discovery, PjBL learning models, science learning, learning activities, self-efficacy, teaching methods, high school, influence, middle school, mathematics projects, teaching materials, and STEM learning.

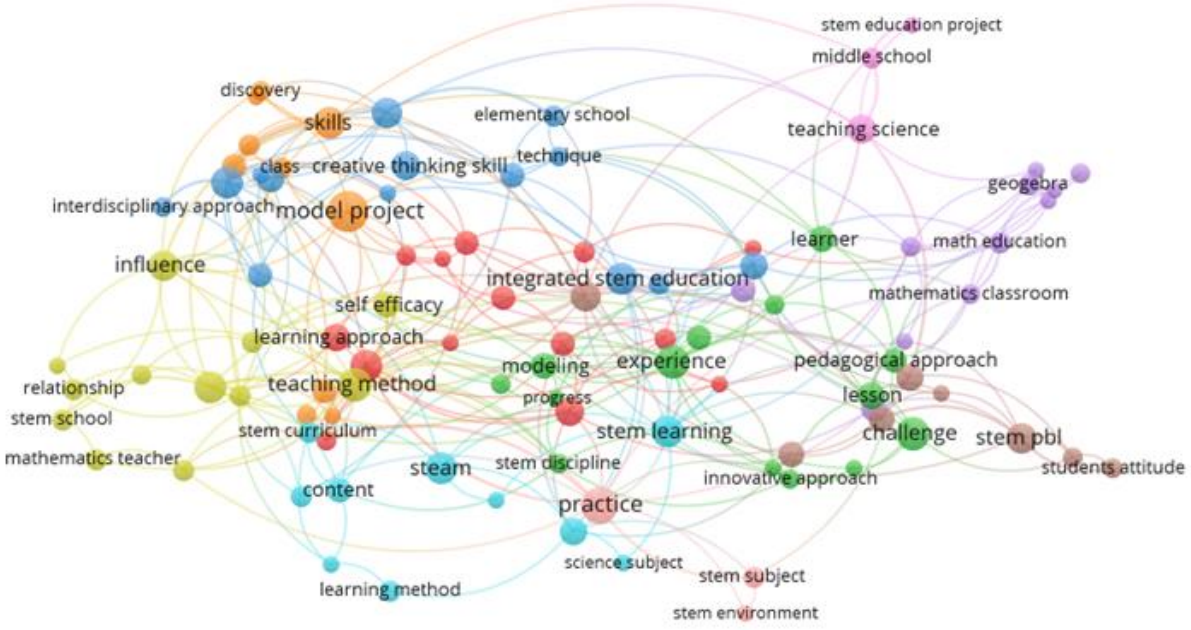


**Fig. 3.** Network visualization of PjBL model with STEM approach in mathematics education keyword

Figure 4 shows the density visualization. Density visualization means that the brighter the yellow colour and the larger the circle diameter marking a term, the more frequently that term occurs [52-54]. This means that much research has been done on related terms. Vice versa, if the colour of a term fades closer to the background colour, the research effort for that term is low. Based on Figure 3, research related to the term teaching method, STEM learning, integrated STEM education, model projects, STEM PjBL, and pedagogical approach had a relatively high number of studies.

Figure 5 visualizes the overlay of Project-Based Learning models and STEM approaches in mathematics education research. This overlay visualization shows the study novelty on related terms [52,53,55]. Figure 5, which is clarified in Figure 6, shows that research on Project-Based Learning models with STEM approaches in mathematics education was mainly conducted in 2019-2020. The popularity of the PjBL model has long been known due to the STEM approach. As such, new research

on Project-Based Learning models using STEM approach in mathematics education can be easily created.

From this data, STEM PjBL was still mainly unrelated to other terms. Mapping results showed that STEM education on PjBL had only 13 links associated with 13 terms. It contrasts with STEM learning and teaching methods, which were highly related and often associated with different terms. From this, we conclude that the Project-Based Learning model with the STEM approach, especially in mathematics education, will likely be further explored and associated with other terms. This will have an even more significant impact on the study novelty.

Based on the attribution of collected dissertation data, the keywords "Project-Based Learning model with a STEM approach for Mathematics Education" had not yet been used in research. Most research papers used only terms or disciplines related to STEM, PjBL, learning, and teaching methods. Based on the findings of this research, research into Project-Based Learning models with newer and more modern STEM approaches, especially in mathematics education, can be advanced.

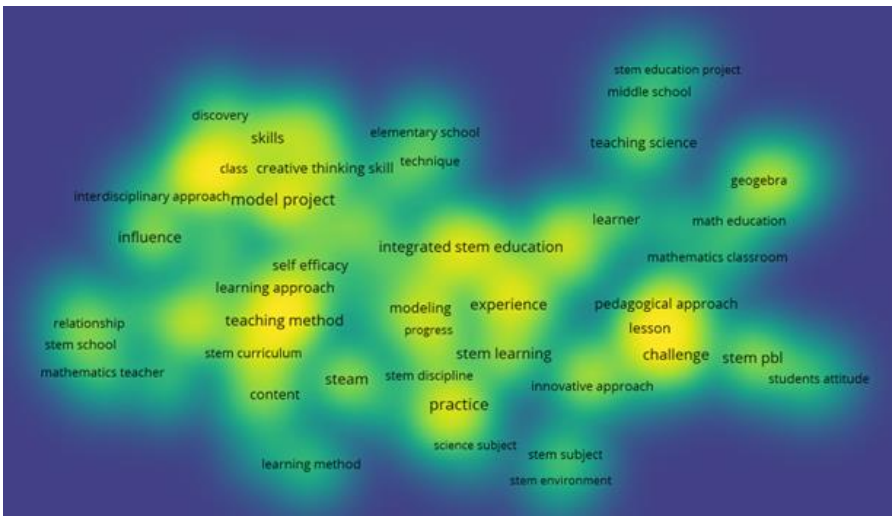


**Fig. 4.** Density visualization of PjBL model with STEM approach in mathematics education keyword

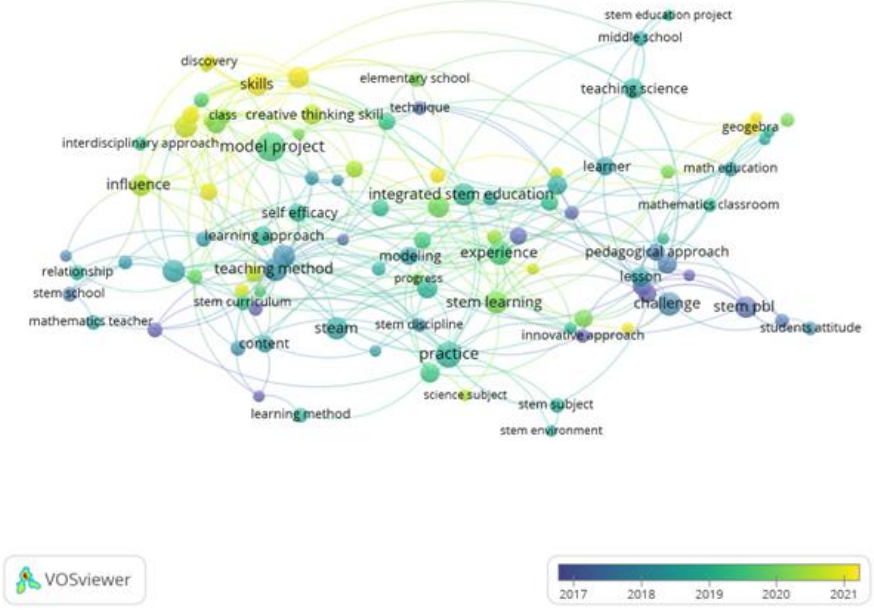


**Fig. 5.** Overlay Visualization of PjBL Model with STEM Approach on Mathematics Education Keyword

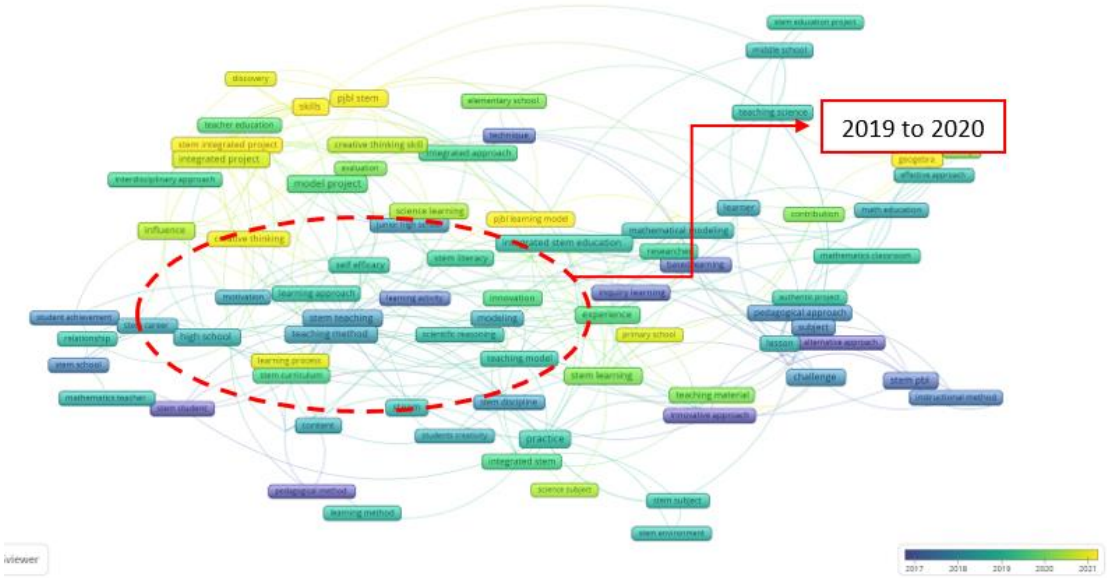


**Fig. 6.** Overlay visualization of Project-Based Learning model with STEM approach in mathematics education from 2019 to 2020

This study gives information for further development as reported elsewhere regarding several subjects:

(i) Mathematics [56-84]
(ii) Biology [85-94]
(iii) Physics [95-100]
(iv) Chemistry [101-107]
(v) Engineering [108-113]

## 4. Conclusions

The study aimed to perform a bibliographic computer-assisted mapping analysis of research articles. The publication theme of this research was "Project-Based Learning model with STEM approach in Mathematics Education". Articles were pulled from the Google Scholar database via Publish or Perish. Library data used in this study included titles and abstracts. Up to 41 relevant articles were published from the search results from 2014 to 2023. The results showed that the Project-Based Learning Model with the STEM approach, especially in mathematics education, had increased from 2014 to 2016 at the same rate in 2016 to 2017. It decreased in 2018, then increased again in 2019 until 2020. It again decreased in 2021 and 2022. Until finally, in 2023, it experienced another increase. Publication figures for year 2023 could continue to increase due to data. This research was taken in the middle of 2023. Research results showed that there were still many research opportunities for Project-Based Learning models with STEM approach, particularly in mathematics education and other related terms.

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## References

[1] Kenedi, Ary Kiswanto, Yullys Helsa, Yetti Ariani, Melva Zainil, and Sherlyane Hendri. "Mathematical Connection of Elementary School Students to Solve Mathematical Problems." *Journal on Mathematics Education* 10, no. 1 (2019): 69-80. https://doi.org/10.22342/jme.10.1.5416.69-80.

[2] Lestari, D.A., Suwarma, I.R., and Suhendi, E. "Feasibility analysis of the development of STEM-based physics e-book with self-regulated learning on global warming topics." *Indonesian Journal of Teaching in Science* 4, no. 1 (2024): 1-10.

[3] Tipmontiane, Krittin, and P. John Williams. "The integration of the engineering design process in biology-related STEM activity: A review of Thai secondary education." *ASEAN Journal of Science and Engineering Education* 2, no. 1 (2022): 1-10. https://doi.org/10.17509/ajsee.v2i1.35097.

[4] Wagiran, W., M. Mujiyono, Bayu Rahmat Setiadi, Yulianto Eko Wibowo, Fredy Surahmanto, Dendy Aqila Agata, and Chinnathan Areeprasert. "Temperature distribution in bio stove using saw dust: An integrated project-based learning." *Indonesian Journal of Science and Technology* 8, no. 1 (2023): 127-140. https://doi.org/10.17509/ijost.v8i1.53476

[5] Purwianingsih, Widi, Dhiya Ananda Lestari, and Taufik Rahman. "Profile of communication skills of students in groups with the application of blended learning using project-based learning model." *Indonesian Journal of Multidiciplinary Research* 3, no. 1 (2023): 159-168.

[6] Nurani, Atat Siti, Ai Mahmudatussa'adah, K. Karpin, Ade Juwaedah, Tati Setiawati, and M. Muktiarni. "Interactive multimedia design of motion graphics using a project-based learning approach for vocational education students: Experiments in cooking taliwang chicken." *ASEAN Journal of Science and Engineering Education* 4, no. 2 (2024): 163-174.

[7] Putra, Rizkie Dwi, and Asri Wibawa Sakti. "Student development: Implementation of water rocket media as a project-based learning tool to improve the literacy of junior high school students during the pandemic." *ASEAN Journal for Science Education* 1, no. 1 (2022): 1-8.

[8] Fatmala, Trie Rizqi, Neneng Windayani, and Ferli Septi Irwansyah. "Application of Project-Based Worksheets for Making Conditioner from Aloe Vera (Aloe vera L.) to Develop Students' Scientific Performance." *ASEAN Journal for Science and Engineering in Materials* 2, no. 2 (2023): 159-168.

[9] Darojah, Teja Zakiah, Neneng Windayani, and Ferli Septi Irwansyah. "Implementing Project-Based Worksheets on Making Kaolin Soap with the Addition of Kefir Curd to develop students' scientific performance in Islamic School." *ASEAN Journal for Science and Engineering in Materials* 3, no. 1 (2024): 59-74.

[10] Wahyuningsih, Nirma, Ahmad Satibi, and Ferry Dwi Cahyadi. "Optimizing Psychomotor Skills through Project-Based Learning in Seaweed Dodol Processing." *ASEAN Journal of Agriculture and Food Engineering* 3, no. 1 (2023): 1-8.

[11] Anazifa, Risqa D., and Djukri Djukri. " Project-Based Learning and Problem-Based Learning: Are They Effective to Improve Student's Thinking Skills? *Jurnal Pendidikan IPA Indonesia* 6, no. 2 (2017): 346-355. https://doi.org/10.15294/jpii.v6i2.11100

[12] Aldabbus, Shaban. "Project-based learning: Implementation & challenges." *International Journal of Education, Learning and Development* 6, no. 3 (2018): 71-79.

[13] Aldabbus, Shaban. "An investigation into the impact of language games on classroom interaction and pupil learning in Libyan EFL primary classrooms." PhD diss., Newcastle University, 2008.

[14] Gubacs, Klara. "Project-based learning: A student-centered approach to integrating technology into physical education teacher education." *Journal of Physical Education, Recreation & Dance* 75, no. 7 (2004): 33-37. https://doi.org/10.1080/07303084.2004.10607272

[15] Maass, Katja, Vince Geiger, Marta Romero Ariza, and Merrilyn Goos. "The role of mathematics in interdisciplinary STEM education." *Zdm* 51 (2019): 869-884. https://doi.org/10.1007/s11858-019-01100-5

[16] Duc, Nguyen Mau, Nguyễn Quang Linh, and Chokchai Yuenyong. "Situation of organizing STEM activities in Vietnamese Schools." In *Journal of Physics: Conference Series*, vol. 1340, no. 1, p. 012030. IOP Publishing, 2019. https://doi.org/10.1088/1742-6596/1340/1/012030

[17] Muhammad, Ilham, Rani Darmayanti, Viky Risnanda Arif, and Adebayo Ola Afolaranmi. "Discovery Learning Research in Mathematics Learning: A Bibliometric Review." *Delta-Phi: Jurnal Pendidikan Matematika* 1, no. 1 (2023): 26-33. https://doi.org/10.24127/ajpm.v12i1.6256

[18] Muhammad, Ilham, and Lilis Marina Angraini. "Research On Students' Mathematical Ability In Learning Mathematics In The Last Decade: A Bibliometric Review." *JOHME: Journal of Holistic Mathematics Education* 7, no. 1 (2023): 108-122. https://doi.org/10.19166/johme.v7i1.6867

[19] Muhammad, Ilham, Christina Monika Samosir, Elmawati Elmawati, and Febrinna Marchy. "Bibliometric Analysis: Adobe Flash Cs6 Research in Mathematics Learning." *JPMI (Jurnal Pendidikan Matematika Indonesia)* 8, no. 1 (2023): 25-34. https://doi.org/10.24235/eduma.v12i1.12607

[20] Sugiarni, Rani, Tatang Herman, Didi Suryadi, Sufyani Prabawanto, and Sarah Inayah. "Research Trends Mathematics Concepts on Pre-Service Mathematics Teachers: A Bibliometric Analysis Using Vosviewer From 2017 To 2022." *PRISMA* 12, no. 1 (2023): 248-262. https://doi.org/10.35194/jp.v12i1.3115
[21] Naser, Abdurrahman Do Muhamad, and Dadang Juandi. "Bibliometric Review: Research on Mathematical Literacy Ability in Mathematics Learning (1979-2023)." *Pedagogy: Jurnal Pendidikan Matematika* 8, no. 1 (2023): 163-180.
[22] Kaymak, Serkan, Bagzhan Maksutkan, and Furkan Yildiz. "A Bibliometric Review on Realistic Mathematics Education Database Between 2000-2022." *International Educational Review* 1, no. 1 (2023): 25-39. https://doi.org/10.31219/osf.io/92acq
[23] Phan, Tinh Thi, Thi Trinh Do, Thanh Hai Trinh, Trung Tran, Huu Tong Duong, Thi Phuong Thao Trinh, Bao Chau Do, and Tien-Trung Nguyen. "A Bibliometric Review on Realistic Mathematics Education in Scopus Database between 1972-2019." *European Journal of Educational Research* 11, no. 2 (2022): 1133-1149. https://doi.org/10.12973/eu-jer.11.2.1133
[24] Dede, Ercan, and Ercan Ozdemir. "Mapping and Performance Evaluation of Mathematics Education Research in Turkey: A Bibliometric Analysis from 2005 to 2021." *Journal of Pedagogical Research* 6, no. 4 (2022): 1-19. https://doi.org/10.33902/JPR.202216829
[25] Suseelan, Menaga, Cheng Meng Chew, and Huan Chin. "Research on Mathematics Problem Solving in Elementary Education Conducted from 1969 to 2021: A Bibliometric Review." *International Journal of Education in Mathematics, Science and Technology* 10, no. 4 (2022): 1003-1029. https://doi.org/10.46328/ijemst.2198
[26] Lada, Suddin, Brahim Chekima, Rudy Ansar, Mohamad Isa Abdul Jalil, Lim Ming Fook, Caroline Geetha, Mohamed Bouteraa, and Mohd Rahimie Abdul Karim. "Islamic Economy and Sustainability: A Bibliometric Analysis Using R." *Sustainability* 15, no. 6 (2023): 5174. https://doi.org/10.3390/su15065174
[27] Zeng, Shaolun, and Huili Yang. "A Bibliometric and Visualization Analysis of Knowledge Mapping in Digital Economy Research, 1992–2022." *Sustainability* 15, no. 8 (2023): 6565. https://doi.org/10.3390/su15086565
[28] Duan, Carson. "A State-of-the-Art Review of Sharing Economy Business Models and a Forecast of Future Research Directions for Sustainable Development: A Bibliometric Analysis Approach." *Sustainability* 15, no. 5 (2023): 4568. https://doi.org/10.3390/su15054568
[29] Zhong, Meihui, and Mingwei Lin. "Bibliometric analysis for economy in COVID-19 pandemic." *Heliyon* 8, no. 9 (2022). https://doi.org/10.1016/j.heliyon.2022.e10757
[30] Zhou, Peng, Yue Lv, and Wen Wen. "The low-carbon transition of energy systems: A bibliometric review from an engineering management perspective." *Engineering* 29 (2023): 147-158. https://doi.org/10.1016/j.eng.2022.11.010.
[31] Duan, Yubing, Yonggui Zhao, Guoqing Ma, Xiaobin Sun, Hao Zhang, and Wenbo Liu. "Development and research trends of a polypropylene material in electrical engineering: A bibliometric mapping analysis and systematical review." *Frontiers in Energy Research* 10 (2023): 1051101. https://doi.org/10.3389/fenrg.2022.1051101
[32] Al Husaeni, Dwi Fitria, and Asep Bayu Dani Nandiyanto. "Bibliometric computational mapping analysis of publications on mechanical engineering education using vosviewer." *Journal of Engineering Science and Technology* 17, no. 2 (2022): 1135-1149.
[33] Wirzal, Mohd Dzul Hakim, and Zulfan Adi Putra. "What is the correlation between chemical engineering and special needs education from the perspective of bibliometric analysis using vosviewer indexed by google scholar." *Indonesian Journal of Community and Special Needs Education* 2, no. 2 (2022): 103-110. https://doi.org/10.17509/ijcsne.v2i2.44581
[34] Nandiyanto, Asep Bayu Dani, and Dwi Fitria Al Husaeni. "Bibliometric analysis of engineering research using vosviewer indexed by google scholar." *Journal of Engineering Science and Technology* 17, no. 2 (2022): 883-894.
[35] Sudrajat, Ujang, Didit Ardianto, and Irvan Permana. "Engineering design process: A review and bibliometric analysis." *International Journal of STEM Education for Sustainability* 2, no. 2 (2022): 180-192. https://doi.org/10.53889/ijses.v2i2.55
[36] Radanliev, Petar, and David De Roure. "New and emerging forms of data and technologies: Literature and bibliometric review." *Multimedia Tools and Applications* 82, no. 2 (2023): 2887-2911. https://doi.org/10.1007/s11042-022-13451-5
[37] Jeflea, Florin Victor, Daniela Danciulescu, Catalina Soriana Sitnikov, Dumitru Filipeanu, Jeong O. Park, and Alexandru Tugui. "Societal technological megatrends: a bibliometric analysis from 1982 to 2021." *Sustainability* 14, no. 3 (2022): 1543. https://doi.org/10.3390/su14031543
[38] Djeki, Essohanam, Jules Dégila, Carlyna Bondiombouy, and Muhtar Hanif Alhassan. "E-learning bibliometric analysis from 2015 to 2020." *Journal of Computers in Education* 9, no. 4 (2022): 727-754. https://doi.org/10.1007/s40692-021-00218-4
[39] Fauzi, Muhammad Ashraf. "E-learning in higher education institutions during COVID-19 pandemic: current and future trends through bibliometric analysis." *Heliyon* (2022). https://doi.org/10.1016/j.heliyon.2022.e09433

[40] Martins, José, Ramiro Gonçalves, and Frederico Branco. "A bibliometric analysis and visualization of e-learning adoption using Vosviewer." *Universal Access in the Information Society* (2022): 1-15. https://doi.org/10.1007/s10209-022-00953-0
[41] Fan, Jingchun, Ya Gao, Na Zhao, Runjing Dai, Hailiang Zhang, Xiaoyan Feng, Guoxiu Shi et al. "Bibliometric analysis on covid-19: a comparison of research between English and Chinese studies." *Frontiers in Public Health* 8 (2020): 477. https://doi.org/10.3389/fpubh.2020.00477
[42] Rosokhata, Anna, Mariia Minchenko, Liliya Khomenko, and Olena Chygryn. "Renewable energy: A bibliometric analysis." In *E3S web of conferences*, vol. 250, p. 03002. EDP Sciences, 2021. https://doi.org/10.1051/e3sconf/202125003002
[43] Bawack, Ransome Epie, Samuel Fosso Wamba, Kevin Daniel André Carillo, and Shahriar Akter. "Artificial intelligence in E-Commerce: a bibliometric study and literature review." *Electronic markets* 32, no. 1 (2022): 297-338. https://doi.org/10.1007/s12525-022-00537-z
[44] Goksu, Idris. "Bibliometric mapping of mobile learning." *Telematics and Informatics* 56 (2021): 101491. https://doi.org/10.1016/j.tele.2020.101491
[45] Yang, Wenting, Jiantong Zhang, and Ruolin Ma. "The prediction of infectious diseases: A bibliometric analysis." *International Journal of Environmental Research and Public Health* 17, no. 17 (2020): 6218. https://doi.org/10.3390/ijerph17176218
[46] Azizah, Nissa Nur, Rina Maryanti, and Asep Bayu Dani Nandiyanto. "How to search and manage references with a specific referencing style using Google Scholar: From step-by-step processing for users to the practical examples in the referencing education." *Indonesian Journal of Multidisciplinary Research* 1, no. 2 (2021): 267-294. https://doi.org/10.17509/ijomr.v1i2.37694
[47] Al Husaeni, Dwi Fitria, and Asep Bayu Dani Nandiyanto. "Bibliometric using Vosviewer with Publish or Perish (using Google Scholar data): From step-by-step processing for users to the practical examples in the analysis of digital learning articles in pre- and post-Covid-19 pandemic." *ASEAN Journal of Science and Engineering* 2, no. 1 (2022): 19-46. https://doi.org/10.17509/ajse.v2i1.37368
[48] Han, Sunyoung, Robert Capraro, and Mary Margaret Capraro. "How science, technology, engineering, and mathematics (STEM) project-based learning (PBL) affects high, middle, and low achievers differently: The impact of student factors on achievement." *International Journal of Science and Mathematics Education* 13 (2015): 1089-1113. https://doi.org/10.1007/s10763-014-9526-0
[49] Ismayani, Ani. "Pengaruh penerapan STEM project-based learning terhadap kreativitas matematis siswa SMK." *Indonesian Digital Journal of Mathematics and Education* 3, no. 4 (2016): 264-272.
[50] Han, Sunyoung, Roslinda Roslı, Mary M. Capraro, and Robert M. Capraro. "The effect of science, technology, engineering and mathematics (STEM) project based learning (PBL) on students' achievement in four mathematics topics." *Journal of Turkish Science Education* 13, no. special (2016): 3-29.
[51] Nandiyanto, Asep Bayu Dani, D. N. Al Husaeni, and D. F. Al Husaeni. "A bibliometric analysis of chemical engineering research using Vosviewer and its correlation with Covid-19 pandemic condition." *Journal of Engineering Science and Technology* 16, no. 6 (2021): 4414-4422.
[52] Nandiyanto, Asep Bayu Dani, and Dwi Fitria Al Husaeni. "A bibliometric analysis of materials research in Indonesian journal using VOSviewer." *Journal of Engineering Research* (2021).
[53] Schrlau, Michael G., Robert J. Stevens, and Sara Schley. "Flipping Core Courses in the Undergraduate Mechanical Engineering Curriculum: Heat Transfer." *Advances in Engineering Education* 5, no. 3 (2016): n3.
[54] Mulyawati, Isah Bela, and Doni Fajar Ramadhan. "Bibliometric and visualized analysis of scientific publications on geotechnics fields." *ASEAN Journal of Science and Engineering Education* 1, no. 1 (2021): 37-46. https://doi.org/10.17509/ajsee.v1i1.32405
[55] Hamidah, Ida, Sriyono Sriyono, and Muhammad Nur Hudha. "A Bibliometric analysis of Covid-19 research using VOSviewer." *Indonesian Journal of Science and Technology* (2020): 34-41. https://doi.org/10.17509/ijost.v5i2.24522
[56] Dallyono, Ruswan, Didi Sukyadi, and Lukman Hakim. "A mathematical model of the cognitive semantics of the English preposition on." *Indonesian Journal of Science and Technology* 5, no. 1 (2020): 133-153. https://doi.org/10.17509/ijost.v5i1.22774
[57] Hashim, Suhaizal, Alias Masek, Bismi Nurnazatul Shima Mohd Mahthir, Ana Haziqah A. Rashid, and Danakorn Nincarean. "Association of interest, attitude and learning habit in mathematics learning towards enhancing students' achievement." *Indonesian Journal of Science and Technology* 6, no. 1 (2021): 113-122. https://doi.org/10.17509/ijost.v6i1.31526
[58] Akinoso, Sabainah Oyebola. "Motivation and ICT in secondary school mathematics using unified theory of acceptance and use of technology model." *Indonesian Journal of Educational Research and Technology* 3, no. 1 (2023): 79-90. https://doi.org/10.17509/ijert.v3i1.47183

[59] Radiamoda, Arsad A. "Difficulties Encountered by the Students in Learning Mathematics." *Indonesian Journal of Educational Research and Technology* 4, no. 1 (2024): 63-70.
[60] Husnah, Annisa Ul, Muhammad Alif Hidayat, and Miftahul Jannah. "The journey of a math: As a mathematics learning innovation." *Indonesian Journal of Multidiciplinary Research* 1, no. 1 (2021): 129-136. https://doi.org/10.17509/ijomr.v1i1.33814.
[61] Marasabessy, Rosida. "Study of mathematical reasoning ability for mathematics learning in schools: A literature review." *Indonesian Journal of Teaching in Science* 1, no. 2 (2021): 79-90. https://doi.org/10.17509/ijotis.v1i2.37950
[62] Maryati, Wahyuni Eka, Endah Retnowati, and Ng Khar Thoe. "Learning mathematics formulas by listening and reading worked examples." *Indonesian Journal of Teaching in Science* 2, no. 1 (2022): 61-74. https://doi.org/10.17509/ijotis.v2i1.45801.
[63] Ogunjimi, Mayowa Olurotimi, and Taofeek Akolade Gbadeyanka. "Effect of guided inquiry and explicit-instructional strategies on lower basic students' academic performance in mathematics." *Indonesian Journal of Teaching in Science* 3, no. 1 (2023): 23-32. https://doi.org/10.17509/ijotis.v3i1.54191.
[64] Obafemi, K. E., U. T. Saadu, A. Adesokan, O. Yahaya, J. T. Sulaimon, T. O. Obafemi, and F. M. Yakubu. "Self-Efficacy as A Correlate of Pupils' Academic Achievement in Mathematics." *Indonesian Journal of Teaching in Science* 3, no. 2 (2023): 113-120. https://doi.org/10.17509/ijotis.v3i2.59775
[65] Mitrayana, M., and Elah Nurlaelah. "Computational Thinking in Mathematics Learning: Systematic Literature Review." *Indonesian Journal of Teaching in Science* 3, no. 2: 133-142. https://doi.org/10.17509/ijotis.v3i2.60179.
[66] Camenda, Datu Yuri, Cybelle Angela Gaba, Nazirev Lacord, Dania Natango, Alecshane Pabl, and Hassanal Abusam. "How difficult is 1+ 1? A phenomenological study of high school students struggling in mathematics." *ASEAN Journal of Science and Engineering Education* 1, no. 2 (2021): 111-116. https://doi.org/10.17509/ajsee.v1i2.33403
[67] Omolafe, Eyiyemi Veronica. "Primary educators experts' validation of the developed mathematics mobile application to enhance the teaching of mathematics in Nigeria primary schools." *ASEAN Journal of Science and Engineering Education* 1, no. 3 (2021): 157-166. https://doi.org/10.17509/ajsee.v1i3.38505
[68] Serra, Elmer JR P., Nikko Jay R. Senope, and Charls M. Lariosa. "Potholes in the implementation of printed module in mathematics and feedbacks of learners in Lambayong national high school during covid-19 pandemic." *ASEAN Journal of Science and Engineering Education* 1, no. 3 (2021): 177-182.
[69] Wijaya, Hanna, Rina Maryanti, Verra Wulandary, and Asep Rudi Irawan. "Numerical minimum competence assessment for increasing students' interest in mathematics." *ASEAN Journal of Science and Engineering Education* 2, no. 3 (2022): 183-192.
[70] Awofala, Adeneye Olarewaju A. "Examining sources of mathematics self-efficacy beliefs of senior secondary school students." *ASEAN Journal of Science and Engineering Education* 3, no. 3 (2023): 229-244.
[71] Awofala, Adeneye Olarewaju A., Oladiran S. Olabiyi, Omolabake T. Ojo, Adenike J. Oladipo, Alfred O. Fatade, and Uchenna N. Udeani. "Personal and contextual factors as correlates of entrepreneurial intentions among pre-service science, technology, and mathematics teachers." *ASEAN Journal of Science and Engineering Education* 3, no. 3 (2023): 265-278.
[72] Obafemi, Kayode Ezecheal, Ayodele Fajonyomi, and Eniola Keji Ola-Alani. "Effect of reversed jigsaw instructional strategy on pupils academic achievement in mathematics." *ASEAN Journal of Science and Engineering Education* 3, no. 3 (2023): 297-304.
[73] Awofala, Adeneye Olarewaju A., Sabainah O. Akinoso, Comfort O. Adeniyi, Sufiyanu H. Jega, Alfred O. Fatade, and Abayomi A. Arigbabu. "Primary teachers' mathematics anxiety and mathematics teaching anxiety as predictors of students' performance in mathematics." *ASEAN Journal of Science and Engineering Education* 3, no. 3 (2024): 291-306.
[74] Obafemi, K. E. "Enhancing pupils' academic performance in mathematics using brainstorming instructional strategy." *ASEAN Journal of Science and Engineering Education* 4, no. 2 (2024): 99-106.
[75] Maryanti, Rina. "Assessment of mathematical abilities of students with intellectual disabilities during the COVID-19 pandemic." *Indonesian Journal of Community and Special Needs Education* 1, no. 2 (2021): 47-52. https://doi.org/10.17509/ijcsne.v1i2.33402.
[76] San Jose, Maria Tricia N. "Factors that affect the performance of selected high school students from the third district of albay in international mathematics competitions." *ASEAN Journal for Science Education* 1, no. 1 (2022): 9-16.
[77] Dermawan, Rian, M. Muktiarni, and Jonah Mupita. "Efforts to increase the interest of junior high school students in mathematics lessons using the tik tok learning tool." *ASEAN Journal for Science Education* 1, no. 2 (2022): 81-88.
[78] Lagcao, Yvrin Gabriel D., Jean Paul Andrei D. Dechavez, Daven John G. Goleng, Alyssa Khate E. Lamzon, Khalid Yasper M. Tangkli, and Welard Jay C. Vicera. "Math readiness and its effect on the online academic performance of science, technology, engineering, and mathematics students." *ASEAN Journal for Science Education* 2, no. 1 (2023): 33-38.

[79] Awofala, Adeneye Olarewaju A., and Afolabi Oladayo Olaniyi. "Assessing teachers' formative evaluation strategy as related to senior secondary school students' achievement in mathematics." *ASEAN Journal for Science Education* 2, no. 2 (2023): 77-86.
[80] Obafemi, K. E., U. T. Saadu, O. Yahaya, T. O. Obafemi, and F. M. Yakubu. "Exploration of the Effect of Scaffolding Instructional Strategy on Pupils' Academic Performance in Mathematics." *ASEAN Journal for Science Education* 2, no. 2 (2023): 121-128.
[81] Awofala, Adeneye Olarewaju A., and Felicia OO Agbolade. "Effect of Peer-Tutoring Strategy on Senior Secondary School Students' Achievement in Mathematics." *ASEAN Journal for Science Education* 3, no. 1 (2023): 1-12.
[82] Padmore, Edward Abanie, and Clement Ayarebilla Ali. "Exploring Effective Differentiated Instruction in The Teaching and Learning of Mathematics." *ASEAN Journal for Science Education* 3, no. 1 (2024): 41-54.
[83] Lasisi, Adekola Kamil, Abdulhafis Adeyinka Hassan, and Habibat Bolanle Abdulkareem. "Impact of single parenting on academic performance of junior secondary school students in mathematics." *ASEAN Journal for Science Education* 3, no. 2 (2024): 129-138.
[84] Nasir, Sharifah Noha Zahirah Syed Abdul, Nurul Ain Ab Wahab, and Mohd Agos Salim Nasir. "Graphical User Interface for Solving Non-Linear Equations for Undergraduate Students." International Journal of Advanced Research in Future Ready Learning and Education 30, no. 1 (2023): 25-34. https://doi.org/10.37934/frle.30.1.2534
[85] Glorifica, Ivonne. "Media analysis of biology teaching book grade xii: A study based on science literation category." *Indonesian Journal of Educational Research and Technology* 1, no. 1 (2021): 17-22. https://doi.org/10.17509/ijert.v1i1.32659
[86] Olumorin, Charles Olabode, Ebenezer Omolafe Babalola, Gboyega Ayodeji Aladesusi, Ahmed Idris Issa, and Eyiyemi Veronica Omolafe. "Experts' validation of the developed 3-dimensional automated model of the human heart to teach a biology concept in Ilorin, Nigeria." *Indonesian Journal of Multidiciplinary Research* 1, no. 2 (2021): 299-308. https://doi.org/10.17509/ijomr.v1i2.37840.
[87] Babalola, Ebenezer Omolafe. "Design and development of 3-dimensional model of human circulatory system to teach a concept of biology in senior secondary schools." *Indonesian Journal of Teaching in Science* 2, no. 1 (2022): 17-28. https://doi.org/10.17509/ijotis.v2i1.39006.
[88] Olumorin, Charles Olabode, Ebenezer Omolafe Babalola, and Desire Adunola Ayoola. "Design and development of human excretory system model to teach a biology concept in Ilorin, Nigeria." *Indonesian Journal of Teaching in Science* 2, no. 2 (2022): 107-116. https://doi.org/10.17509/ijotis.v2i2.45782
[89] Hofifah, Siti Nur, and S. Sumiati. "The effectiveness of the practicum video guide on distance learning in improving biology learning outcomes in enzyme content." *Indonesian Journal of Teaching in Science* 3, no. 2 (2023): 201-212. https://doi.org/10.17509/ijotis.v3i2.62905
[90] Alhassan, Najmuddeen, Amina Alhassan, and Akazi Frances Chioma. "Examining the role of biology teachers' beliefs, motivations, and self-reported practices in constructing curves for biology class." *Indonesian Journal of Teaching in Science* 4, no. 1 (2024): 11-26.
[91] Tipmontiane, Krittin, and P. John Williams. "The integration of the engineering design process in biology-related STEM activity: A review of Thai secondary education." *ASEAN Journal of Science and Engineering Education* 2, no. 1 (2022): 1-10. https://doi.org/10.17509/ajsee.v2i1.35097.
[92] Abdussemiu, Ahmad. "Problems of teaching practical biology in senior secondary schools." *ASEAN Journal of Science and Engineering Education* 2, no. 3 (2022): 199-206.
[93] Babalola, Ebenezer Omolafe, Desire Adunola Ayoola, and Eyiyemi Veronica Omolafe. "Analysis of Experts' Opinion on the Human Excretory System Model for Teaching Biology in Nigeria." *ASEAN Journal of Science and Engineering Education* 3, no. 1: 19-26.
[94] Ala, N. A., A. O. Onojah, A. M. Ishyaku, and S. B. Adamu. "Development of an Animation Package in Biology for Teaching Vertebrate, Anatomy, and Physiology." *ASEAN Journal for Science Education* 1, no. 2 (2022): 117-130.
[95] Susilowati, Nisfullail Indah, Winny Liliawati, and Dadi Rusdiana. "Science process skills test instruments in the new indonesian curriculum (merdeka): Physics subject in renewable energy topic." *Indonesian Journal of Teaching in Science* 3, no. 2 (2023): 121-132. https://doi.org/10.17509/ijotis.v3i2.60112
[96] Lestari, D.A., Suwarma, I.R., and Suhendi, E. "Feasibility analysis of the development of STEM-based physics e-book with self-regulated learning on global warming topics." *Indonesian Journal of Teaching in Science* 4, no. 1 (2024): 1-10.
[97] Abosede, P. J., S. A. Onasanya, and O. C. Ngozi. "Students self-assessment of demonstration-based flipped classroom on senior secondary school students' performance in physics." *Indonesian Journal of Teaching in Science* 4, no. 1 (2024): 27-40.
[98] Azizah, Elza Varih, Asep Bayu Dani Nandiyanto, Tedi Kurniawan, and Muhammad Roil Bilad. "The effectiveness of using a virtual laboratory in distance learning on the measurement materials of the natural sciences of physics for junior high school students." *ASEAN Journal of Science and Engineering Education* 2, no. 3 (2022): 207-214.

[99] Ibrahim, Abdulwaheed Opeyemi. "Impact of blended learning method on secondary school physics students' achievement and retention in Lokoja, Nigeria." *ASEAN Journal for Science Education* 2, no. 2 (2023): 57-66.
[100] Phang, Fatin Aliah, Victor Kayode Ojomoh, and Nina Diana Nawi. "The Effect of the Virtual Laboratory Method on the Conceptual Understanding of Thermal Physics among Undergraduates." *International Journal of Advanced Research in Future Ready Learning and Education* 34, no. 1 (2024): 124-130. https://doi.org/10.37934/frle.34.1.124130
[101] Francis, Torpev Terver, and Salaudeen Jaleel Baba. "Effect of concept mapping teaching approach on students' academic performance in chemistry in senior secondary schools." *Indonesian Journal of Educational Research and Technology* 3, no. 1 (2023): 69-78. https://doi.org/10.17509/ijert.v3i1.46145.
[102] Putri, Silmi Ridwan, Siti Nur Hofifah, Gabriela Chelvina Santiuly Girsang, and Asep Bayu Dani Nandiyanto. "How to identify misconception using certainty of response index (cri): a study case of mathematical chemistry subject by experimental demonstration of adsorption." *Indonesian Journal of Multidiciplinary Research* 2, no. 1 (2021): 143-158. https://doi.org/10.17509/ijomr.v2i1.38738
[103] Wirzal, Mohd Dzul Hakim, and Nur Syakinah Abd Halim. "Short Play Approach for Analytical Chemistry Class." *ASEAN Journal of Science and Engineering Education* 2, no. 2 (2022): 163-168. https://doi.org/10.17509/ajsee.v2i2.42762
[104] Barke, Hans-Dieter, and Joline Buechter. "Laboratory jargon and misconceptions in Chemistry–an empirical study." *ASEAN Journal of Science and Engineering Education* 3, no. 1 (2023): 65-70.
[105] Sombria, Khezel Jean F., Diane L. Celestial, Clea Grace M. Jalagat, and Anamarie G. Valdez. "Online learning through google classroom: Effects on students critical thinking skills in chemistry." *ASEAN Journal of Science and Engineering Education* 3, no. 2 (2023): 193-210.
[106] Swafiyah, Bawa, Binta Asabe Muhammad, and Abdullahi Zaharaddeen Yamusa. "Effect of Conceptual Change Instructional Strategy on Chemistry Students' Performance in Acids and Bases Concepts." *ASEAN Journal for Science Education* 2, no. 1 (2023): 47-54.
[107] Bilad, Muhammad Roil. "Bibliometric analysis for understanding the correlation between chemistry and special needs education using VOSviewer indexed by google." *ASEAN Journal of Community and Special Needs Education* 1, no. 2 (2022): 61-68.
[108] Sambudi, Nonni Soraya, and Raihan Mahirah Ramli. "Integrated project as innovative assessment to enhance learning experience in thermodynamics class." *ASEAN Journal of Science and Engineering Education* 1, no. 3 (2021): 167-176. https://doi.org/10.17509/ajsee.v1i3.40896
[109] Harith, K. "Exploring Historical Seismic Events Through Secondary Data Analysis: Implications for Understanding Submarine Earthquakes in Marine Geophysics for Educational Purposes." *Indonesian Journal of Multidiciplinary Research* 3, no. 2 (2023): 349-370.
[110] Bilad, Muhammad Roil, and Saiful Prayogi. "Portfolio workbook as an effective method for student-centered learning of chemical engineering principles." *ASEAN Journal of Science and Engineering Education* 1, no. 1 (2021): 31-36. https://doi.org/10.17509/ajsee.v1i1.32404
[111] Andika, Riezqa, and Zulfan Adi Putra. "Teaching programming to chemical engineering students." *ASEAN Journal of Science and Engineering Education* 2, no. 1 (2022): 51-60. https://doi.org/10.17509/ajsee.v2i1.36935
[112] Samsuri, Shafirah. "Teaching Chemical Engineering Thermodynamics using Substituted Blended Learning Techniques." *ASEAN Journal of Science and Engineering Education* 4, no. 2: 143-162.
[113] Wirzal, Mohd Dzul Hakim, and Zulfan Adi Putra. "What is the correlation between chemical engineering and special needs education from the perspective of bibliometric analysis using VOSviewer indexed by google scholar." *Indonesian Journal of Community and Special Needs Education* 2, no. 2 (2022): 103-110. https://doi.org/10.17509/ijcsne.v2i2.44581
[114] Cinar, Sinan, Nimet Pirasa, and Gunay Palic Sadoglu. "Views of Science and Mathematics Pre-Service Teachers Regarding STEM." *Universal Journal of Educational Research* 4, no. 6 (2016): 1479-1487. https://doi.org/10.13189/ujer.2016.040628
[115] Bicer, Ali, Bilgin Navruz, Robert M. Capraro, Mary M. Capraro, T. A. Oner, and Peter Boedeker. "STEM schools vs. non-STEM schools: Comparing students' mathematics growth rate on high-stakes test performance." *International Journal of New Trends in Education and Their Implications* 6, no. 1 (2015): 138-150. https://doi.org/10.1109/FIE.2015.7344245
[116] Hadiyanti, N. F. D., A. C. Prihandoko, R. P. Murtikusuma, N. Khasanah, and P. Maharani. "Development of mathematics e-module with STEM-collaborative project based learning to improve mathematical literacy ability of vocational high school students." In *Journal of Physics: Conference Series*, vol. 1839, no. 1, p. 012031. IOP Publishing, 2021. https://doi.org/10.1088/1742-6596/1839/1/012031

[117] Lee, Yujin, Robert M. Capraro, and Ali Bicer. "Affective mathematics engagement: A comparison of STEM PBL versus non-STEM PBL instruction." *Canadian Journal of Science, Mathematics and Technology Education* 19 (2019): 270-289. https://doi.org/10.1007/s42330-019-00050-0
[118] Widana, I. Wayan, and Kadek Lisa Septiari. "Kemampuan berpikir kreatif dan hasil belajar matematika siswa menggunakan model pembelajaran Project-Based Learning berbasis pendekatan STEM." *Jurnal Elemen* 7, no. 1 (2021): 209-220. https://doi.org/10.29408/jel.v7i1.3031
[119] Priatna, Nanang, Silviana Lorenzia, and Sri Adi Widodo. "STEM education at junior high school mathematics course for improving the mathematical critical thinking skills." *Journal for the Education of Gifted Young Scientists* 8, no. 3 (2020): 1173-1184. https://doi.org/10.17478/jegys.728209
[120] Octaviyani, Indri, Yaya Sukjaya Kusumah, and Aan Hasanah. "Peningkatan kemampuan berpikir kreatif matematis siswa melalui model project-based learning dengan pendekatan stem." *Journal on Mathematics Education Research (J-MER)* 1, no. 1 (2020): 10-14.
[121] Viro, Elina, Daranee Lehtonen, Jorma Joutsenlahti, and Ville Tahvanainen. "Teachers' perspectives on project-based learning in mathematics and science." (2020). https://doi.org/10.30935/scimath/9544
[122] Jacques, Lorraine A. "What does project-based learning (PBL) look like in the mathematics classroom." *American Journal of Educational Research* 5, no. 4 (2017): 428-433.
[123] Craft, Ashley M., and Robert M. Capraro. "Science, technology, engineering, and mathematics project-based learning: Merging rigor and relevance to increase student engagement." *Electronic International Journal of Education, Arts, and Science (EIJEAS)* 3, no. 6 (2017).
[124] Capraro, Mary Margaret, and Sandra B. Nite. "STEM integration in mathematics standards." *Middle Grades Research Journal* 9, no. 3 (2014): 1-10.
[125] Bowen, Bradley D., and Bryanne Peterson. "Exploring authenticity through an engineering-based context in a project-based learning mathematics activity." (2019). https://doi.org/10.7771/2157-9288.1073
[126] Luneeva, Olga L., and Venera G. Zakirova. "Integration of mathematical and natural-science knowledge in school students' project-based activity." *EURASIA Journal of Mathematics, Science and Technology Education* 13, no. 7 (2017): 2821-2840. https://doi.org/10.12973/eurasia.2017.00720a
[127] Chalim, Muhammad Nur, Scolastika Mariani, and Kristina Wijayanti. "Kemampuan Komunikasi Matematis Siswa SMK Ditinjau dari Self Efficacy pada Setting Pembelajaran Project Based Learning Terintegrasi STEM." In *PRISMA, Prosiding Seminar Nasional Matematika*, vol. 2, pp. 540-550. 2019.
[128] Anindayati, Arista Tri, and Wahyudi Wahyudi. "Kajian pendekatan pembelajaran STEM dengan model pjbl dalam mengasah kemampuan berpikir kreatif matematis siswa." *EKSAKTA: Jurnal Penelitian Dan Pembelajaran MIPA* 5, no. 2 (2020): 217-225. https://doi.org/10.31604/eksakta.v5i2.217-225
[129] Evans, Riley, Jane Friedman, Lynn McGrath, Perla Myers, and Amanda Ruiz. "Math path: Encouraging female students in mathematics through project-based learning." *Primus* 28, no. 4 (2018): 287-299. https://doi.org/10.1080/10511970.2017.1339154
[130] Hakim, Luki, Yayu Sulastri, Achmad Mudrikah, and Deti Ahmatika. "STEM project-based learning models in learning mathematics to develop 21st century skills." In *Proceedings of the 1st International Conference on Science and Technology for an Internet of Things,* 20 October 2018, Yogyakarta, Indonesia. https://doi.org/10.4108/eai.19-10-2018.2281357