



BERKALA ILMIAH PENDIDIKAN FISIKA

<https://ppjp.ulm.ac.id/journal/index.php/bipf>

Bibliometric Analysis of Problem Based Learning in Physics Education: A Scopus Based Study (1996-2023)

Siti Nurjanah^{1*}, Jumriani Sultan¹, Siti Aisyah², Dita Puspita³, and Nur Ulyasari⁴

¹Educational Research and Evaluation, Yogyakarta State University,
Yogyakarta, Indonesia

²Chemistry Education, Yogyakarta State University, Yogyakarta, Indonesia

³Physics Education, Tanjungpura University, Pontianak, Indonesia

⁴English Education, Tanjungpura University, Pontianak, Indonesia

*siti960pasca.2023@student.uny.ac.id

DOI:10.20527/bipf.v12i2.18583

Received: 19 February 2024 Accepted: 9 July 2024 Published: 2 August 2024

Abstract

Using the Scopus database, this study analyzed and mapped the productivity, citation patterns, and collaborative research on Problem-Based Learning (PBL) in Physics Education. The method used was bibliometric, using the Scopus database. A total of 58 articles published between 1996 and 2023 were analyzed. The findings indicate a steady increase in publications from 1996 to 2019, with a decline during the COVID-19 pandemic years. The Asia Pacific Forum on Science Learning and Teaching emerged as the leading journal, with major contributions from the State University of Surabaya and the University of Rwanda. The most influential authors and articles were identified, and key research trends were highlighted. This bibliometric analysis provides a foundation for future research on PBL approaches in physics education.

Keywords: bibliometric analysis; physics education; problem based learning; scopus

© 2024 Berkala Ilmiah Pendidikan Fisika

How to cite: Nurjanah, S., Sultan, J., Aisyah, S., Puspita, D., & Ulyasari, N. (2024). Bibliometric analysis of problem based learning in physics education: A scopus based study (1996-2023). *Berkala Ilmiah Pendidikan Fisika*, 12 (2), 310-326.

INTRODUCTION

Studying physics aims to help students understand the ideas they have learned from books, educational materials, or their surroundings (Mubarrok & Mulyaningsih, 2014; Nurjanah et al., 2022; Sari et al., 2017). In this instance, conceptual comprehension refers to the student's capacity to grasp theory and formula, which they can combine to create a more comprehensible version (Prastowo et al., 2017; Putra et al., 2018). But while learning physics, students frequently struggle to grasp these abstract ideas and apply them to real-world situations (Kartini et al., 2024). Effective learning approaches, such as a

PBL framework, can address these challenges.

The PBL model utilizes real-world problems as a means for students to acquire knowledge (Diani et al., 2019). This model necessitates that learners gain knowledge, develop problem-solving abilities, and acquire skills for participating in group activities (Diani et al., 2018). PBL is an effective approach for supporting physics education, as it encourages learners to solve physics-related problems independently (Yulianti et al., 2021). The advantages of the PBL include: 1) the problem-solving



process effectively supports students' comprehension of the lesson content, 2) problem-solving takes place during the learning process, challenging the ability of the student and giving satisfaction, 3) can improve the learning activity, 4) develop the self-control of the learner, 5) develop the ability to solve the problem of the apprentice, 6) stimulate the student to learn continuously (Eviyanti, 2017). Students are encouraged to collaborate in groups, think critically, and apply the physics principles they have learned to actual problems through PBL. Furthermore, this learning paradigm can assist students in creating connections between physics theory and application, holistically enhancing their understanding of physics subjects (Ayudha & Setyarsih, 2021).

PBL helped students acquire physics concepts by involving them directly in solving real problems related to the subject matter. In addition to improving concept understanding, PBL also developed critical thinking and analytical skills and applied these physics theories practically (Magdalena et al., 2024). For example, when learning Newton's laws, students may be given problems such as designing a safe and efficient roller coaster. This process forces them to apply physics knowledge about force, mass, and acceleration to make their understanding deeper and more meaningful (Yanti et al., 2024). PBL makes learning more interesting and equips students with problem-solving skills that could be applied outside the classroom.

Currently, research on the PBL has been extensively applied in the context of physics education. Applications of PBL also have a very diverse orientation, ranging from learning achievement (Fidan & Tuncel, 2019; Mundilarto & Ismoyo, 2017; Yance, 2013), critical thinking skills (Jatmiko et al., 2018; Mundilarto & Ismoyo, 2017; Samadun & Dwikoranto, 2022), learning motivation and problem-solving skills (Argaw et al., 2016; Hudha et al., 2017), concept understanding (Sahin, 2010a), communication and collaboration

skills (Saldo & Walag, 2020) and so on. Besides, PBL in physics learning has also been integrated with various aspects such as augmented reality (Fidan & Tuncel, 2019), virtual media (Hastuti et al., 2017) context-based learning (Yuberti et al., 2019), STEM (Pane et al., 2021), and others. The variety of research on PBL in physics education indicates that this area of study is expanding, not only in its focus but also in its integration. To better understand the trends in this research, further investigation is necessary (Supriadi et al., 2022).

Conducting a bibliometric analysis on the theme of PBL is crucial to identifying the challenges and opportunities in physics education. This is because bibliometric analysis can present information about patterns of literary development more effectively and efficiently. This analysis can be the next reference for researchers to understand scientific research's structure, dynamics, and impact on this topic (Oluwadele et al., 2023). Bibliometric analysis measures a written work mathematically and statistically (Diodato & Gellatly, 2013) that aims to understand the structure of knowledge and explore the trend of research development (Bornmann & Leydesdorff, 2014). Compared to experience-based methods, bibliometric analysis has the advantage of collecting and processing large volumes of technical information. Additionally, the results of a bibliometric analysis are more objective and can assist researchers in delving deeper into scientific and technical texts to uncover specific patterns of change (Huang et al., 2020). According to (Julia et al., 2020), the bibliometric analysis examines seven key areas: (1) publication trends, (2) the journals that most frequently publish articles on a topic, (3) the most widely cited articles, (4) the keywords

most commonly used by authors in a topic's publications, (5) author collaboration networks, (6) institutional collaboration patterns, and (7) overall statistical trends.

The researchers revealed that this bibliometric analysis effectively provided broad information about research trends. This is demonstrated by the findings by (Ng et al., 2023), which provide information on the effectiveness of bibliometrics in identifying challenges and opportunities in management education and analyzing the characteristics of research and research themes that often emerge in management education from 2020-2023 by reviewing 920 articles from the Scopus. In addition, research from Puspita et al. (2023) also showed that bibliometric analysis can provide information on research trends on PBL in primary schools from 2017-2021 using 98 source articles from national and international journals. Then, (Huang et al., 2020) research also showed results that bibliometrics is effective for analyzing major topics that often emerge in educational research and trends in education research, as topics little attention is paid to in pedagogical research. The bibliometric analysis of PBL on physics learning has already been done by Burhanudin (2023). Still, the study only analyzes sources from the last ten years, namely from 2013-2013, so it has not analyzed how the productivity of PBL on physics learning has been since it was first published.

The primary goal of physics education is to help students acquire theoretical concepts and apply them to real-world situations. However, students often struggle with abstract ideas. PBL is an effective approach that uses real-world problems to facilitate knowledge acquisition and skill development. This study aims to conduct a bibliometric analysis of PBL in physics education to identify trends, key contributors, and potential future research directions.

METHOD

This study used the Scopus database to collect data on PBL in physics education from 1996 to 2023. This is because Scopus has a fast, functional database update that can be used to facilitate, analyze citations, calculate research collaborations, publish productivity annually and export data to Microsoft Excel for further tabulation and mapping (Campbell et al., 2024; Oluwadele et al., 2023). A total of 58 articles were identified using specific search criteria.

A database search using Scopus consists of several steps, namely identifying a record through a basic search in Scopus. Then, search by limiting the search physics AND problem AND based AND learning to article, abstract, and keyword features. Education OR educational OR pedagogy OR pedagogies OR teach OR teaching OR teacher on source title feature. Social sciences are a subject area feature. Then, we restricted the document type to articles, so we got the publication data of 58 articles.

The data were analyzed using R Studio with the 'Biblioshiny' package, allowing for visualization and analysis of bibliometric indicators such as publication productivity, active authors, and key research trends. R Studio is an easy-to-use software with the advantage of complete features in bibliometric analysis, and data can be further analyzed by exporting data to Microsoft Excel (Zhang et al., 2022). Rstudio is able to visualize and analyze bibliometrical indicators such as annual publication productivity, active authors and collaborations, related journals, countries, and keywords used in PBL research in Physics Education (Ibrahim et al., 2023; López Belmonte et al., 2020). The bibliometric analysis method used in research is shown in Figure 1. Figure 1 illustrates the bibliometric analysis flowchart.

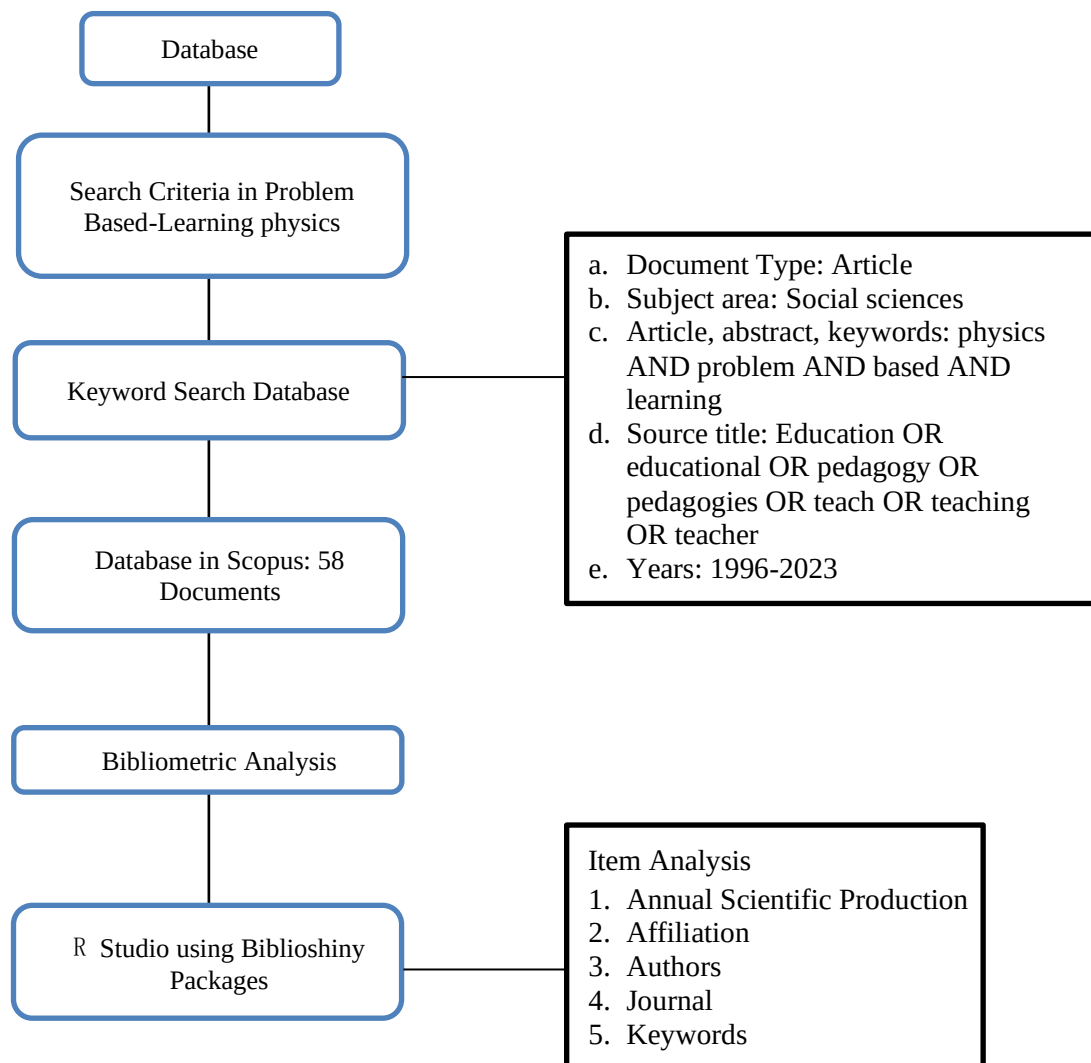


Figure 1 Bibliometric analysis flowchart

The eligible records were obtained from the Scopus database and exported as a .csv file. Subsequently, RStudio was opened, and the following syntaxes were entered: (1) "library (bibliometrix)". This syntax activates the bibliometrix function within the running RStudio application. (2) "(biblioshiny)". This syntax launches the biblioshiny feature. After executing these two syntaxes, the biblioshiny web interface appears. This web interface provides various features containing bibliometric analyses that researchers can utilize to analyze their research data. The .csv data from the Scopus database was

inputted on this web interface as the bibliometric study analysis data.

RESULT AND DISCUSSION

Publication productivity of PBL in physics education on the Scopus database

The first research on the topic was published in 1996, followed by a publication pause until 2003. Starting in 2003, the number of articles published on PBL in physics education began to rise. This upward trend continued until it stopped in 2007-2008 because no articles on this topic were published in those two years. Publications rose again in 2009-

2011, then decreased in 2012-2014. Significant increases occurred in 2017-2019, followed by significant decreases in the subsequent period up to 2022, and returned to rise in 2023. Figure 2 shows the annual publication trends.

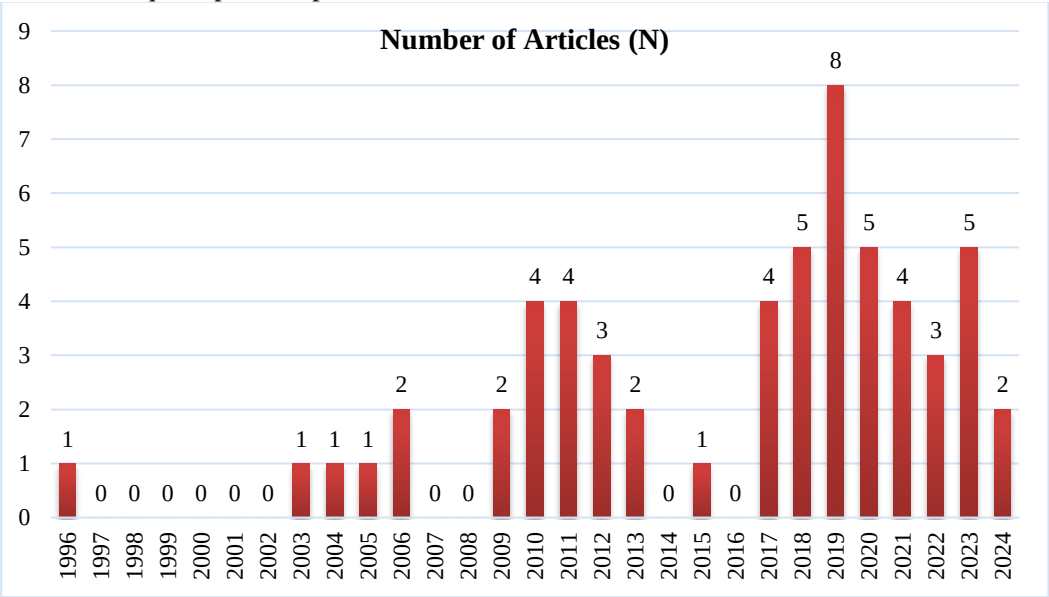


Figure 2 Number of articles published each year

Based on the publication data obtained, the Dokuz Eylul University of Turkey and the Surabaya State University of Indonesia are the institutions with the highest productivity, with nine papers published. Table 1 provides a detailed data on the top institutions.

Table 1 Publication profile on PBL in Physics Education

Category	Top 10 Publications
Affiliation	Universitas Negeri Surabaya (9); University of Rwanda (9); Dokuz Eylul Üniversitesi (6); Mordovia State Pedagogical Institute Named After M. E. Evsevev (4); School of Physics (4); Universitas Islam Negeri Raden Intan (4); Univesiti Sains Malaysia (4); Graduate School of Yogyakarta State University (3); Instituto Tecnológico (3); Mbarara University of Science and Technology (3); Nanyang Technological University (3)

The most famous publications, authors, and articles on PBL in physics education

The research articles were published in 40 different journals. Each journal had a different impact, as shown by the number of quotations from the journal, the author, and the article's title. Table 2 provides detailed data on the top journals. Of these ten journals, the top five are "Asia Pacific Forum on Science Learning and Teaching" with 4 articles (6.9%), "Eurasia Journal of Mathematics Science

and Technology Education" with three articles (5.2%), "International Journal of Learning Teaching and Educational Research" with 3, "Journal for the Education of Gifted Young Scientists" with 3, and "Proceedings Frontiers in Education Conference FIE" with three articles (5,2%). Based on the ten journals, the Asia Pacific Forum on Science Learning and Teaching accounts for more than 6% of the total of 37 publications, making the largest contribution to publishing research in the

context of PBL in physics education, and recommended as one of the target

journals for future researchers on the topic.

Table 2 Top 11 Journals on research PBL in physics education

Journal	Number of documents	Percentage
Asia Pacific Forum on Science Learning and Teaching	4	6.9%
Eurasia Journal of Mathematics Science and Technology Education	3	5.2%
International Journal of Learning Teaching and Educational Research	3	5.2%
Journal for the Education of Gifted Young Scientists	3	5.2%
Proceedings Frontiers in Education Conference Fie	3	5.2%
European Journal of Engineering Education	2	3.4%
International Journal of Evaluation and Research in Education	2	3.4%
Journal of Baltic Science Education	2	3.4%
Journal of Technology and Science Education	2	3.4%
Physics Review Physics Education Research	2	3.4%

Figure 3 presents the top 11 journals on PBL in physics education reviewed by the number of quotations. Of the 11

journals identified, "Computers and Education" has the greatest impact with 200 citations.

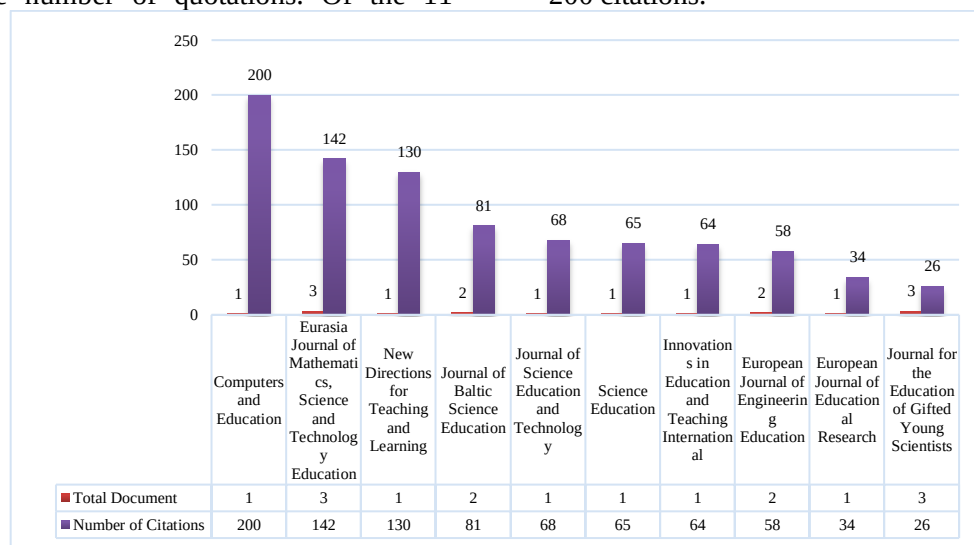


Figure 3 Top 10 journals in research for PBL in physics education

The most active and influential authors on the topic of PBL in physics education were then identified by the number of their publications and quotations. Of the 58 articles published in the Scopus database, 158 authors have contributed to this field. Of these, Gumisirizah, N. (Rwanda), Muwonge, C.M. (Uganda), and Nzabahimana, J. (Ruanda) are the authors with the most contributions for each three articles published. Furthermore, based on the

number of citations, Fidan, M. (Turkey) is the most influential author with 200 article citations. Table 3 provides detailed data on the top authors based on documents.

Table 3 Top ten productive authors

Authors	Country	Document
Gumisirizah, N.	Gumisirizah, N.	3
Muwonge, C.M.	Muwonge, C.M.	3
Nzabahimana, J.	Nzabahimana, J.	3
Gunawan, G.	Gunawan, G.	2
Herayanti, L.	Herayanti, L.	2
Kanyesigye, S.T.	Kanyesigye, S.T.	2
Kemeza, I.	Kemeza, I.	2

Authors	Country	Document
Prahani, B.K.	Prahani, B.K.2	2
Sahin, M.	Sahin, M.2	2
Uwamahoro, J.	Uwamahoro, J.2	2

Table 4 provides detailed data on the top institutions based on citations.

Table 4 Top ten influential authors

Authors	Country	Citation
Fidan, M.	Turkey	200
Tuncel, M.	Turkey	200
Allen, D. E.	United States	130
Duch, B. J.	United States	130
Groh, S. E.	United States	130
Sahin, M.	Turkey	104
Argaw, A. S.	Ethiopia	94
Ayalew, B. T.	Ethiopia	94
Haile, B. B.	Ethiopia	94
Kuma, S. G.	Ethiopia	94

Based on the number of articles published in the Scopus database and cited by other researchers, we have identified the articles with the greatest influence on PBL in physics education. Of the 58 titles published in the Scopus database, the article "Integrating Augmented Reality into Problem-based Learning: The Effects on Learning Achievement and Attitude in Physics Education," written by Fidan and Tuncel, has the highest number of citations: 200. Further details are shown in Table 5, which provides detailed data on the top influential articles.

Table 5 Ten most influential articles

Title	Reference	Journal	Citation
Integrating augmented reality into problem-based learning: The effects on learning achievement and attitude in physics education	(Fidan & Tuncel, 2019)	Computers and Education	200
The power of problem-based learning in teaching introductory science courses	(Allen et al., 1996)	New directions for teaching and learning Eurasia Journal of	130
The effect of problem-based learning (PBL) instruction on students' motivation and problem-solving skills of physics	(Argaw et al., 2016)	Mathematics, Science and Technology Education	94
Effects of Problem-based Learning on university students' Epistemological Beliefs about physics and physics learning and Conceptual Understanding of Newtonian Mechanics	(Sahin, 2010a)	Journal of Science Education and Technology	68
Experimental analysis of the effective components of problem-based learning	(Pease & Kuhn, 2011)	Science Education	65
Effects of a problem-based learning program on engineering students' academic achievements in a Mexican university	(Polanco * et al., 2004)	Innovations in Education and Teaching International	64
The comparison of oripa teaching model and problem-based learning model effectiveness to improve critical thinking skills of pre-service physics teachers	(Jatmiko et al., 2018)	Journal of Baltic Science Education	44
Effect of problem-based learning on improvement physics achievement and Critical Thinking of senior high school student	(Mundilarto & Ismoyo, 2017)	Journal of Baltic Science Education	37
The impact of problem-based learning on engineering students' beliefs about physics and conceptual understanding of energy and momentum	(Sahin, 2010b)	European Journal of Engineering Education	36
Approaching problem-solving skills of momentum and impulse phenomena using context and problem-	(Yuberti et al., 2019)	European Journal of Educational	34

	Title	Reference	Journal	Citation
	based learning		Research	

The most frequently emerging keywords and trends in PBL in physics education in the Scopus database over time

This analysis identifies the major areas of study that are the research focus and builds a conceptual framework. This analysis can also highlight significant developments in the study of PBL in physics education. Using the biblioshiny package, we investigated with a focus on keywords plus. 98 keywords were found in 58 articles indexed in the Scopus

database. These keywords are then analyzed to see the frequency of occurrence and trends of the keywords over time. Figure 3 shows the key word trends that often appear on this topic. The ten most commonly found keywords include problem-based learning (7), students (7), teaching (6), engineering education (5), learning systems (5), computer-aided instruction (3), curricula (3), problem-solving (3), e-learning (2), and learning activity (2).

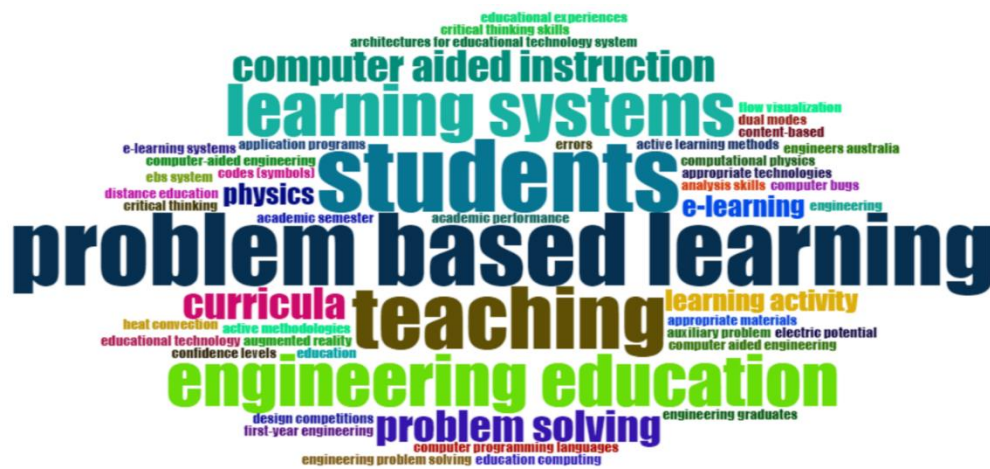


Figure 3 Frequently appearing word trends

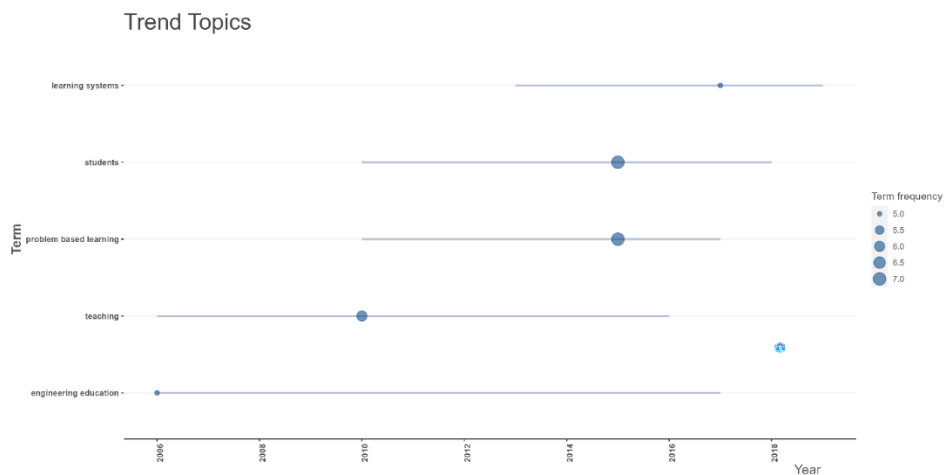


Figure 4 Topic trends over time

Figure 4 shows the most discussed word trends over time on the topic of PBL in physics learning. The study of engineering education gained popularity in the early years of PBL. 2010 saw the rise of the teaching trend. PBL and students rose in popularity in 2015 simultaneously as populist terms. Learning systems have become a popular term in this field in recent years.

Allen et al. (1996) conducted the first research on PBL in physics education in 1996. This article covers the use of PBL in college-level basic science courses. It discusses the distinctions between PBL and conventional lecture-based teaching methods and how PBL may inspire and involve students in collaborative, active learning. The page also covers evaluations, real-world problem situations, and learning tools that can be used in PBL for scientific courses.

From 1996 to 2024, the subject continued to grow. The increase started in 2003, and there was a significant increase in 2019 with 8 articles. A significant upward trend can occur because both researchers and physics education instructors have realized the potential of PBL to streamline physics learning. Many studies prove PBL to be an effective learning model that improves the quality of learning as well as student quality (Bassir et al., 2014; Bati, 2023; Jamal et al., 2019; Ramdani et al., 2023; Romano Daba et al., 2019; Sharma et al., 2023; Zheng et al., 2023). However, a significant decrease occurred precisely after a period of significant increases in the number of publications on this topic. This could be due to the inhibition of research due to Covid-19 pandemic (Mannen, 2023; Šipilova, 2023). There's a lockdown policy, learning isn't carried out in a row, and many countries are still adapting to new learning settings. Development of articles in the last five years, namely 2019 (8 articles), 2020 (5 articles), 2021 (4 articles), 2022 (3

articles), 2023 (5 articles). Based on the data, we can see a progressive increase in research interest in the topic of PBL in physics education, and this is potentially to be developed in further research.

Over the past few decades, publication trends related PBL in physics education have exhibited various fluctuations, reflecting advancements and challenges in this field. A bibliometric analysis reveals that publication productivity experienced a steady increase from 1996 to 2019, followed by a decline during the COVID-19 pandemic. These fluctuations can be interpreted as the result of several factors, including shifts in research priorities, the availability of funding, and logistical and operational challenges faced by researchers during this period. A deeper understanding of these trends is crucial not only for identifying the progress that has been made but also for planning the direction of future research, considering the factors that influence publication productivity.

The Asia Pacific Forum on Science Learning and Teaching has significantly contributed to the field of PBL in physics education by publishing influential research. This journal has been instrumental in disseminating innovative teaching methods, including the integration of technology like augmented reality to enhance student engagement and learning outcomes. Studies published in APFSLT have provided empirical evidence on the effectiveness of PBL, particularly in improving students' critical thinking and problem-solving skills. Additionally, the journal has fostered international collaboration among researchers, creating a global community dedicated to advancing science education. These contributions not only advance the academic promotion of researchers but also drive the development of effective educational practices in physics. This journal can be a destination for researchers who want to

research this topic. Choosing the right journal not only helps the development of science but also the academic promotion of an academic (Shamsi et al., 2023).

Gumisirizah N. has made significant contributions to PBL in physics education through his prolific research output. As a PhD student at the University of Rwanda, his focus on PBL highlights his dedication to exploring effective teaching methods that enhance students' understanding of physics concepts. His work has provided valuable insights into the implementation of PBL and its impact on developing critical thinking and problem-solving skills among students. Dr. Mustafa Fidan, the most cited author in this field, has also made remarkable contributions through his expertise in educational technology and curriculum development. His research on the integration of augmented reality (AR) into PBL is highly influential, demonstrating the positive effects of AR on students' learning achievements and attitudes towards physics. Fidan's development of internet-based evaluation systems for tablet computers further underscores his commitment to using technology to improve educational outcomes. His work has set a benchmark in applying innovative technologies in education, significantly advancing the field of PBL in physics education.

The article by Fidan and Tuncel in 2019 was the most cited article on this topic. This article discusses integrating augmented reality technology into PBL and its impact on learning achievements and attitudes towards physics subjects in education. The most cited article's findings align with other research findings that AR positively influences the academic achievement of students in science education (Kalemkuş & Kalemkuş, 2023). Moreover, several studies (Cano et al., 2017; Chen et al., 2016; Makhataeva & Varol, 2020) also say that AR plays a significant role in

students' motivation influencing the outcome of cognitive achievements.

The top ten most cited articles primarily discuss the effectiveness of PBL in enhancing various aspects of physics education, particularly conceptual understanding, problem-solving skills, critical thinking, and students' positive attitudes towards the subject. These articles are frequently cited because they provide robust empirical evidence demonstrating the superiority of PBL methods over traditional teaching approaches in physics education, utilizing various valid research designs and measurement instruments. The main contribution of these studies to the field of PBL in physics education is the identification of effective components of PBL (such as the focus on engagement with problems) and the demonstration of its efficacy in improving various aspects of physics learning, including conceptual understanding, higher-order thinking skills, and students' positive attitudes.

The most frequently emerging keyword findings of the 58 articles analyzed describe the development of research PBL in physics education. Keywords such as students, teaching, and learning activity reflect a more student-centred application of learning in physics, which is in line with the theory of learning constructivism. PBL has improved student learning activity (Bana et al., 2022; Hincapié Parra et al., 2018). In addition, Computer-aided instruction and e-learning integrate interactive multimedia and computer simulations to enhance student engagement in PBL physics. This trend is in line with Wilson's findings in 2023 that technology has a positive effect on attitudes and beliefs. In addition, a 2013 study by Kim and Kim found that e-learning positively impacted learning effectiveness.

Research on keyword trends in PBL physics articles consistently illustrates the evolution of focus and research

approaches in this field. In the early stages of PBL research in physics, engineering education emerged as a prominent keyword. This indicates the roots of PBL application, which began in engineering education. Subsequently, in 2010, teaching became a primary keyword, reflecting that early PBL physics learning was still focused on teaching methods and roles. By 2015, the keywords students and PBL dominated, indicating that PBL physics research had shifted to a more student-centered approach with active and PBL concepts, as seen in Figure 2.

The integration of technology has become increasingly important, as reflected by the emergence of keywords like "computer-aided instruction" and "e-learning". Liu and Pásztor (2022) demonstrated how digital tools can effectively support PBL implementation in physics education. Interdisciplinary approaches have also gained attention, with "engineering education" emerging as a major keyword, signifying a trend towards integrating physics concepts with practical engineering applications (Garcia-Martin et al., 2017).

The focus on skill development, particularly problem-solving, has become a central theme in PBL physics research. Ritonga & Areeisty (2021) emphasized the importance of PBL in facilitating conceptual change and enhancing critical thinking skills. Curriculum design has also received special attention, with Fitri and Asrizal (2023) exploring how PBL can be integrated into the physics curriculum to enhance self-efficacy and critical thinking abilities in pre-service teachers.

Active learning experiences and teaching effectiveness have become other significant focuses. Uluçınar (2023) reviewed the impact of PBL on students' academic achievement, while Raman et al. (2024) investigated the effects of PBL on conceptual understanding, scientific reasoning, and problem-solving skills in

thermodynamics. For example, in a case study, students were given a real-world problem related to thermodynamics to solve. They had to apply the physics principles they had learned to design an efficient cooling system. This process not only deepened their understanding of thermodynamic concepts but also enhanced their collaborative and problem-solving skills.

The role of PBL in physics education is highly significant in helping students develop a deep understanding of physics concepts through contextual and relevant learning experiences. As an example of its application, in a physics course on Newton's laws, students might be given a real-world problem, such as designing a bridge that can withstand a certain load. In solving this problem, students would need to apply Newton's laws to calculate the forces acting on the bridge and determine the appropriate construction materials. This activity not only helps students understand Newton's laws in a practical manner but also develops their critical thinking, collaboration, and problem-solving skills. These findings reflect a paradigm shift in physics education towards a more interactive, student-centred approach, with PBL as a key method for achieving complex learning objectives relevant to the demands of the 21st century.

CONCLUSION

This bibliometric analysis reveals an increasing interest in PBL in physics education, with significant contributions from specific journals and institutions. The journal that has published the most articles on this subject is the Asia Pacific Forum on Science Learning and Teaching. The analysis identifies key authors and articles that have shaped the field. The most productive individual contributors are researchers from Rwanda and Uganda, and the most prominent author in terms of citation count is Fidan from Turkey. The 2019

study by Fidan and Tuncel, which has received the most citations on using augmented reality in PBL physics, is a significant piece on this subject. According to a keyword analysis of works in this field, the study focus has shifted from engineering education and teaching to the use of learning systems in PBL for physics education. Based on the main findings, practical suggestions were that researchers need to strengthen collaboration networks between authors and institutions, both locally and internationally, to expand insights and innovations in PBL. Technology like augmented reality should be further explored to improve learning effectiveness. Future research should explore the integration of innovative pedagogical approaches in PBL to enhance physics education. Researchers were also advised to publish research on this topic in relevant journals, such as the Asia-Pacific Forum on Science Learning and Teaching. In addition, it was necessary to analyze the collaboration network of authors and institutions to understand the dynamics and improve synergy in PBL research. This study was limited to the Scopus database. Future research should incorporate other databases, like the Web of Science, to ensure a more comprehensive literature review.

REFERENCES

- Allen, D. E., Duch, B. J., & Groh, S. E. (1996). The power of problem-based learning in teaching introductory science courses. *New Directions for Teaching and Learning*, 1996(68), 43–52. <https://doi.org/10.1002/tl.37219966808>
- Argaw, A. S., Haile, B. B., Ayalew, B. T., & Kuma, S. G. (2016). The effect of problem based learning (pbl) instruction on students' motivation and problem solving skills of physics. *EURASIA Journal of Mathematics, Science and Technology Education*, 13(3). <https://doi.org/10.12973/eurasia.2017.00647a>
- Ayudha, C. F. H., & Setyarsih, W. (2021). Studi literatur: Analisis praktik pembelajaran fisika di SMA untuk melatih keterampilan pemecahan masalah. *Jurnal Pendidikan Fisika Undiksha*, 11(1), 16. <https://doi.org/10.23887/jjpf.v11i1.33427>
- Bana, K. F. M., Shamim, M. S., & Shahid, Z. (2022). Self-assessment of active learning and critical thinking during problem-based learning: An exploratory study. *Journal of the Pakistan Medical Association*, 72(9), 1771–1774. <https://doi.org/10.47391/JPMMA.4473>
- Bassir, S. H., Sadr-Eshkevari, P., Amirikhorheh, S., & Karimbux, N. Y. (2014). Problem-based learning in dental education: A systematic review of the literature. *Journal of Dental Education*, 78(1), 98–109.
- Bati, K. (2023). Investigation of the effect of online problem-based learning on achievement, attitude, motivation, and group dynamics: A systematic literature review. *Hacettepe Egitim Dergisi*, 38(1), 134–143. <https://doi.org/10.16986/HUJE.2022.462>
- Bornmann, L., & Leydesdorff, L. (2014). Scientometrics in a changing research landscape. *EMBO Reports*, 15(12), 1228–1232. <https://doi.org/10.15252/embr.201439608>
- Cano, S., Collazos, C. A., Flórez Aristizábal, L., & Moreira, F. (2017). *Augmentative and alternative communication in the literacy teaching for deaf children* (pp. 123–133).

- https://doi.org/10.1007/978-3-319-58515-4_10
- Chen, C.-H., Chou, Y.-Y., & Huang, C.-Y. (2016). An augmented-reality-based concept map to support mobile learning for science. *The Asia-Pacific Education Researcher*, 25(4), 567–578. <https://doi.org/10.1007/s40299-016-0284-3>
- Diani, R., Khotimah, H., Khasanah, U., & Syarlisjswan, M. R. (2019). Scaffolding dalam pembelajaran fisika berbasis problem based instruction (pbl): Efeknya terhadap pemahaman konsep dan self efficacy. *Indonesian Journal of Science and Mathematics Education*, 2(3), 310–319.
- Diani, R., Yuberti, Y., & Syarlisjswan, M. R. (2018). Web-enhanced course based on problem-based learning (pbl): Development of interactive learning media for basic physics II. *Jurnal Ilmiah Pendidikan Fisika Al-Biruni*, 7(1), 105–116. <https://doi.org/10.24042/jipfalbiruni.v7i1.2849>
- Diodato, V. P., & Gellatly, P. (2013). *Dictionary of Bibliometrics*. Routledge. <https://doi.org/10.4324/9780203714133>
- Eviyanti, C. Y. (2017). Improving the students' mathematical problem solving ability by applying problem based learning model in VII grade at SMPN 1 Banda Aceh Indonesia. *International Journal of Novel Research in Education and Learning*, 4(2), 138–144.
- Fidan, M., & Tuncel, M. (2019a). Integrating augmented reality into problem based learning: The effects on learning achievement and attitude in physics education. *Computers & Education*, 142, 103635. <https://doi.org/10.1016/j.compedu.2019.103635>
- Fitri, A. D., & Asrizal. (2023). Development of physics e-module integrated with pbl model and ethnoscience to improve students' 21st century skills. *Jurnal Penelitian Pendidikan IPA*, 9(12), 10610–10618. <https://doi.org/10.29303/jppipa.v9i12.5877>
- Garcia-Martin, J., Enrique Pérez-Martínez, J., Garcí'a, J., Garcí'a-Martí'n, G., Martí'n, M., Pé Rez-Martí'nez, J. E., & Martí'nez, M. (2017). Method to guide the design of project based learning activities based on educational theories. In *Article in International Journal of Engineering Education*. <https://www.researchgate.net/publication/317754122>
- Hastuti, A., Sahidu, H., & Gunawan, G. (2017). Pengaruh model PBL berbantuan media virtual terhadap kemampuan pemecahan masalah fisika. *Jurnal Pendidikan Fisika Dan Teknologi*, 2(3), 129–135. <https://doi.org/10.29303/jpft.v2i3.303>
- Hincapié Parra, D. A., Ramos Monobe, A., & Chrino-Barceló, V. (2018). Problem based learning as an active learning strategy and its impact on academic performance and critical thinking of medical students. *Revista Complutense de Educacion*, 29(3), 665–681. <https://doi.org/10.5209/RCED.53581>
- Huang, C., Yang, C., Wang, S., Wu, W., Su, J., & Liang, C. (2020). Evolution of topics in education research: a systematic review using bibliometric analysis. *Educational Review*, 72(3), 281–297. <https://doi.org/10.1080/00131911.2019.1566212>
- Hudha, M. N., Aji, S., & Rismawati, A. (2017). Pengembangan modul pembelajaran fisika berbasis Problem Based Learning untuk

- meningkatkan kemampuan pemecahan masalah fisika. *SEJ (Science Education Journal)*, 1(1), 36–51.
<https://doi.org/10.21070/sej.v1i1.830>
- Ibrahim, Z. S., Rifqiyah, F., Sultan, J., & Retnawati, H. (2023). A visualized bibliometric analysis for mapping research trends of machine learning in academic research. *Materials of International Practical Internet Conference “Challenges of Science,”* 271–279.
<https://doi.org/10.31643/2023.34>
- Jamal, S. N. B., Ibrahim, N. H. B., & Surif, J. B. (2019). Concept cartoon in problem-based learning: A systematic literature review analysis. *Journal of Technology and Science Education*, 9(1), 51–58.
<https://doi.org/10.3926/jotse.542>
- Jatmiko, B., Prahani, B. K., Munasir, M., Imam Supardi, Z. A., Wicaksono, I., Erlina, N., Pandiangan, P., Althaf, R., & Zainuddin, Z. (2018). The comparison of or-IPA teaching model and problem based learning model effectiveness to improve critical thinking skills of pre-service physics teachers. *Journal of Baltic Science Education*, 17(2), 300–319.
<https://doi.org/10.33225/jbse/18.17.300>
- Julia, J., Afrianti, N., Ahmed, K., Supriyadi, T., Dolifah, D., Isrokatun, I., Erhamwilda, E., & Ningrum, D. (2020). Flipped classroom educational model (2010-2019): A bibliometric study. *European Journal of Educational Research*, 9(4), 1377–1392.
<https://doi.org/10.12973/eu-jer.9.4.1377>
- Kalemkuş, J., & Kalemkuş, F. (2023). Effect of the use of augmented reality applications on academic achievement of student in science education: meta analysis review. *Interactive Learning Environments*, 31(9), 6017–6034.
<https://doi.org/10.1080/10494820.2022.2027458>
- Kartini, I., Pohan, L. R., Lubis, P. A. A., & Toruan, S. M. L. (2024). Implementasi problem based learning untuk meningkatkan pemahaman konsep siswa: Studi pustaka. *Ideguru: Jurnal Karya Ilmiah Guru*, 9(1), 256–263.
<https://doi.org/10.51169/ideguru.v9i1.819>
- Liu, Y., & Pásztor, A. (2022). Effects of problem-based learning instructional intervention on critical thinking in higher education: A meta-analysis. *Thinking Skills and Creativity*, 45, 101069.
<https://doi.org/10.1016/j.tsc.2022.101069>
- López Belmonte, J., Segura-Robles, A., Moreno-Guerrero, A.-J., & Parra-González, M. E. (2020). Machine learning and big data in the impact literature. A bibliometric review with scientific mapping in web of science. *Symmetry*, 12(4), 495.
<https://doi.org/10.3390/sym12040495>
- Magdalena, I., Agustin, E. R., & Fitria, S. M. (2024). Konsep model pembelajaran (The concept of learning model). *Sindoro: Cendikia Pendidikan*, 3(1), 1–10.
- Makhataeva, Z., & Varol, H. (2020). Augmented reality for robotics: A review. *Robotics*, 9(2), 21.
<https://doi.org/10.3390/robotics9020021>
- Mannen, T. (2023). Effect of the COVID-19 pandemic on research activities in the laboratory: Changes in the initial education program and meeting style. *2023 IEEE 10th International Conference on E-Learning in Industrial Electronics, ICELIE 2023*.
<https://doi.org/10.1109/ICELIE58531.2023.10313097>

- Mubarrok, M. F., & Mulyaningsih, S. (2014). Penerapan pembelajaran fisika pada materi cahaya dengan media PhET simulations untuk meningkatkan pemahaman konsep siswa di SMP. *Jurnal Inovasi Pendidikan Fisika*, 3(1), 76–80.
- Mundilarto, M., & Ismoyo, H. (2017). Effect of problem-based learning on improvement physics achievement and critical thinking of senior high school student. *Journal of Baltic Science Education*, 16(5), 761–779. <https://doi.org/10.33225/jbse/17.16.761>
- Ng, D. T. K., Ching, A. C. H., & Law, S. W. (2023). Online learning in management education amid the pandemic: A bibliometric and content analysis. *The International Journal of Management Education*, 21(2), 100796. <https://doi.org/10.1016/j.ijme.2023.100796>
- Nurjanah, S., Djudin, T., & Hamdani. (2022). Analisis kemampuan berpikir kritis peserta didik pada topik fluida dinamis (Analysis of students' critical thinking skills on the topic of dynamic fluid). *Jurnal Education and Development*, 10(03), 111–116.
- Oluwadele, D., Singh, Y., & Adeliyi, T. T. (2023). Trends and insights in e-learning in medical education: A bibliometric analysis. *Review of Education*, 11(3). <https://doi.org/10.1002/rev3.3431>
- Pane, A. N., Andra, D., & Wayan Distrik, I. (2021). The development physics e-module based PBL–Integrated STEM to improve higher-order thinking skills on static fluid material. *Journal of Physics: Conference Series*, 1796(1), 012086. <https://doi.org/10.1088/1742-6596/1796/1/012086>
- Pease, M. A., & Kuhn, D. (2011). Experimental analysis of the effective components of problem-based learning. *Science Education*, 95(1), 57–86. <https://doi.org/10.1002/sce.20412>
- Polanco, R., Calderón, P., & Delgado, F. (2004). Effects of a problem-based learning program on engineering students' academic achievements in a Mexican university. *Innovations in Education and Teaching International*, 41(2), 145–155. <https://doi.org/10.1080/1470329042000208675>
- Prastowo, S. H. B., Puspitasari, D., & Prihandono, T. (2017). Analisis pemahaman konsep siswa tentang elastisitas di kelas XI SMA. *Prosiding Seminar Nasional Pendidikan Fisika*.
- Putra, I. A., Sujarwanto, E., & Pertiwi, N. A. S. (2018). Analisis pemahaman konseptual mahasiswa pada materi kinematika partikel melalui tes diagnostik. *Jurnal Riset Dan Kajian Pendidikan Fisika*, 5(1), 10. <https://doi.org/10.12928/jrpkf.v5i1.8923>
- Raman, Y., Surif, J., & Ibrahim, N. H. (2024). The effect of problem based learning approach in enhancing problem solving skills in chemistry education: A systematic review. *International Journal of Interactive Mobile Technologies (IJIM)*, 18(05), 91–111. <https://doi.org/10.3991/ijim.v18i05.47929>
- Ramdani, D., Susilo, H., Suhadi, S., & Sueb, S. (2023). The effect of problem based learning on critical thinking skills of biology learning in indonesia: A meta-analysis study. In H. H. & F. N. (Eds.), *AIP Conference Proceedings* (Vol. 2569). American Institute of Physics Inc. <https://doi.org/10.1063/5.0112352>
- Ritonga, S., & Areeisty, K. (2021). Asian journal of science education enhancing students' critical thinking

- skills through problem based learning integrated with mindmapping. *Asian Journal of Science Education*, 3(1), 63–69. <http://jurnal.unsyiah.ac.id/AJSE/>
- Romano Daba, J. B., Rosmansyah, Y., & Dabarsyah, B. (2019). Problem based learning using gamification: A systematic literature review. *Proceedings-1st International Conference on Informatics, Multimedia, Cyber and Information System, ICIMCIS 2019*, 125–130. <https://doi.org/10.1109/ICIMCIS48181.2019.8985216>
- Sahin, M. (2010a). Effects of problem-based learning on university students' epistemological beliefs about physics and physics learning and conceptual understanding of newtonian mechanics. *Journal of Science Education and Technology*, 19(3), 266–275. <https://doi.org/10.1007/s10956-009-9198-7>
- Sahin, M. (2010b). The impact of problem-based learning on engineering students' beliefs about physics and conceptual understanding of energy and momentum. *European Journal of Engineering Education*, 35(5), 519–537. <https://doi.org/10.1080/03043797.2010.487149>
- Samadun, S., & Dwikoranto, D. (2022). Improvement of student's critical thinking ability sin physics materials through the application of problem-based learning. *IJORER : International Journal of Recent Educational Research*, 3(5), 534–545. <https://doi.org/10.46245/ijorer.v3i5.247>
- Sari, W. P., Suyanto, E., & Suana, W. (2017). Analisis pemahaman konsep vektor pada siswa sekolah menengah atas. *Jurnal Ilmiah Pendidikan Fisika Al-Biruni*, 6(2), 159–168. <https://doi.org/10.24042/jipfalbiruni.v6i2.1743>
- Shamsi, A., Lund, B. D., Seyyed Hosseini, S., & Basirian Jahromi, R. (2023). Journal selection behavior among early-career academicians in Iran: how they choose the most appropriate journal for their publications. *Global Knowledge, Memory and Communication*, 72(3), 315–326. <https://doi.org/10.1108/GKMC-09-2021-0146>
- Sharma, S., Saragih, I. D., Tarihoran, D. E. T. A. U., & Chou, F.-H. (2023). Outcomes of problem-based learning in nurse education: A systematic review and meta-analysis. *Nurse Education Today*, 120. <https://doi.org/10.1016/j.nedt.2022.105631>
- Šipilova, V. (2023). COVID-19 lockdown effects on education: A review of themes, education fields, and challenges within academic research. *International Journal of Organizational Diversity*, 23(2), 59–88. <https://doi.org/10.18848/2328-6261/CGP/v23i02/59-88>
- Supriadi, U., Supriyadi, T., Abdussalam, A., & Ali, A. (2022). A decade of value education model: A bibliometric study of scopus database in 2011-2020. *European Journal of Educational Research*, 11(1), 557–571. <https://doi.org/10.12973/eu-jer.11.1.557>
- Uluçınar, U. (2023). The Effect of problem-based learning in science education on academic achievement: A meta-analytical study. *Science Education International*, 34(2), 72–85. <https://doi.org/10.33828/sei.v34.i2.1>

- Yance, R. D. (2013). Pengaruh penerapan model project based learning (pbl) terhadap hasil belajar fisika siswa kelas xi ipa sma negeri 1 batipuh kabupaten tanah datar. *Pillar of Physics Education*, 1. <https://doi.org/10.24036/490171074>
- Yanti, D., Silitonga, H. T. M., & Hidayatullah, M. M. S. (2024). Implementasi pembelajaran diferensiasi berbasis model problem based learning meningkatkan hasil belajar siswa kelas VII. *Seroja: Jurnal Pendidikan*, 3(1), 127–135.
- Yuberti, Y., Antomi, Y., Saregar, A., Latifah, S., Anugrah, A., Misbah, M., & Jermisittiparsert, K. (2019). Approaching the problem-solving skills of momentum and impuls phenomena using Context and problem-based learning (c-pbl). *European Journal of Educational Research*, 8(4), 1217–1227. <https://doi.org/10.12973/eu-jer.8.4.1217>
- Yuliastanti, R., Astutik, S., & Subiki, S. (2021). Model pembelajaran berbasis masalah (pbm) disertai teknik scaffolding dalam pembelajaran fisika di sma. *Jurnal Pembelajaran Fisika*, 3(3), 248–253.
- Zhang, J., Yu, N., Wang, B., & Lv, X. (2022). Trends in the use of augmented reality, virtual reality, and mixed reality in surgical research: A global bibliometric and visualized analysis. *Indian Journal of Surgery*, 84(S1), 52–69. <https://doi.org/10.1007/s12262-021-03243-w>
- Zheng, Q.-M., Li, Y.-Y., Yin, Q., Zhang, N., Wang, Y.-P., Li, G.-X., & Sun, Z.-G. (2023). The effectiveness of problem-based learning compared with lecture-based learning in surgical education: a systematic review and meta-analysis. *BMC Medical Education*, 23(1). <https://doi.org/10.1186/s12909-023-04531-7>