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Research Trend of Integration of Problem Based Learning in Laboratory Activities: *A Bibliometric Analysis*

Aulia Ajizah[1,2*], N. Nahadi[3], Chairil Faif Pasani[4], Encep Syarief Nurdin[1]

[1] General and Character Education Department, Universitas Pendidikan Indonesia, Jl. Dr. Setiabudi Bandung 40154, Indonesia
[2] Biology Education Department, Universitas Lambung Mangkurat, Jl. Brigjen H. Hasan Basry, Banjarmasin 70123, Indonesia
[3] Chemistry Education Department, Universitas Pendidikan Indonesia, Jl. Dr. Setiabudi Bandung 40154, Indonesia
[4] Mathematics Education Department, Universitas Lambung Mangkurat, Jl. Brigjen H. Hasan Basry, Banjarmasin 70123, Indonesia

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Corresponding Author:
Aulia Ajizah
auliaajizah@upi.edu

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Abstract: This article is written to analyze the research trends regarding the integration of the Problem Based Learning (PBL) model in laboratory practical activities over the past 10 years (2014–2023). The method employed is Bibliometric Analysis, supported by the VOSviewer application. The analysis focused on titles and abstracts, encompassing 961 scientific articles from international journals indexed in Scopus over the last decade. Data collection was performed through searches using the keyword "Problem Based Learning in Laboratory Activities." The search results reveal network formation, overlays, and trend direction graphs over the past 10 years. The research yields the following data: 1) The total number of publication articles based on keywords is 961 documents, which are filtered down to 453 documents, 2) The country with the highest contribution to published articles is the USA with 194 documents, 3) Co-occurrence analysis shows variations in article topics with six clusters, and 4) Overlay Visualization indicates that articles on laboratory activities tend to focus on the learning system, student-related aspects, curriculum, and problem-solving.

Keywords: Bibliometric Analysis; Laboratory Activities; Problem Based Learning

Introduction

Problem Based Learning (PBL) is a crucial educational strategy for curriculum integration, student motivation, problem identification in learning, and setting individual learning goals. When applied, PBL has proven to enhance learning outcomes (Bahri, Palennari, Hardianto, Muharni, & Arifuddin, 2021), influencing student motivation by 100% and learning outcomes by 95% (Safitri, Hadi, Widiasih, 2023). PBL accommodates student learning activity (Yennita & Zukmadini, 2021) and enhances critical thinking among learners (Reis, Barbalho, Zanette, 2017); (Zahrah, Halim, Hasan, 2018).

The essence of Problem-Based Learning (PBL) lies in presenting various problematic and meaningful situations to learners, acting as a springboard for investigation and inquiry (Arends, 2008) in (Nurfadhillah, Elmiati, Putri, 2022). In other words, problem-based learning teaches learners to initiate the learning process with a problem that needs to be solved, resulting in the acquisition of new knowledge. One characteristic of the PBL model is authentic investigation, where learners strive to find solutions by collecting and analyzing data, conducting experiments, making inferences, and drawing conclusions (Prasetyanti, 2016). The syntax of PBL provides students with the opportunity to learn independently, enhance motivation and discipline, and engage in collaborative inquiry with their peers (Bahri, et al, 2021). During laboratory activities, learners are given the opportunity to experience or perform tasks, follow a process, observe an object, analyze, prove, and draw conclusions (Khairunnufus, Laksmiwati, Hadisaputra, & Siahaan, 2019). PBL-based laboratory activities can enhance students' critical thinking skills and scientific attitudes (Zahrah et al., 2018). Some researchers develop

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laboratory guides based on PBL syntax (Yanti, Silaban, & Sitorus, 2018).

PBL can challenge students to learn how to learn, work in groups, and find solutions to problems. Using this learning approach makes learners active and creative during practice, guiding them to work scientifically (Susanti, Sari, Supriyatno, & Riandi, 2017). It is believed that the increase in students' creative thinking in the experimental class is due to the implementation of PBL, because PBL is designed to develop thinking skills, problem solving and intellectual skills (Khairunnisa et al., 2022). PBL-based science laboratory modules have improved students' problem-solving skills in practical activities (Wahyudiana, Sagita, Iasha, Setiantini, & Setiarini, 2021). The PBL approach in engineering education shows an increase in students' absorption of technical content and the development of soft skills and multidisciplinary (Reis, et al, 2017).

PBL can enhance students' learning outcomes (Bahri, et al, 2021); (Argaw, Haile, Ayalew, & Kuma, 2017) and motivate students to achieve deep learning (Harun, Yusof, Jamaludin, & Hassan, 2012)., and learning motivation, understanding, teacher and student interactions were significantly higher than the traditional group (Wanjun Zhao, Linye He, Wenyi Deng, Jingqiang Zhu, Anping Su, 2020), although the effects of PBL on motivating physics learning are still unclear (Argaw, et al, 2017). PBL can significantly stimulate achievement motivation in students (Sari, 2018). The implementation of PBL provides space for students to be active and independent in assembling knowledge (Permata et al., 2022). When combined with flashcard media, PBL influences students' creative thinking abilities on the topic of Environmental Pollution (Khairunnisa et al., 2022). and critical thinking skills with the PBL model are better compared to students taught with the direct learning model (Khairani; Suyanti; Saragi, 2020). The results of bibliometric analysis of PBL in Chemistry Education by Tosun; Senocak; Taskesenligil, (2021) shown that the keywords most frequently used include problem solving, problem-based learning, laboratory learning.

The integration of PBL and science can develop students' abilities in designing experiments and enhancing scientific reasoning skills (Gallagher, Sher, Stepien, & Workman, 2023). Implementing PBL is one way teachers foster 21st-century skills (Getingoz, 2023). The integration of PBL and cooperative scripts can empower critical thinking skills of biology students (Boleng & Maasawet, 2019). The existence of PBL in the curriculum at the institutional level allows research on the principles of applied PBL and the potential for its sustainable integration in engineering curricula (Guerra, 2017). Consequently, numerous articles discuss the integration of PBL in laboratory practical guides, especially in the fields of science, physics, chemistry, and engineering. PBL has been extensively discussed and researched in many countries. In the effort to search for articles related to Problem-Based Learning (PBL) through the Scopus database from the period 2014-2023, numerous articles have examined the integration of PBL in laboratory practical guides and its application in laboratory activities. These articles cover various aspects, including the instructional model, its influence on learning outcomes, its impact on psychomotor skills, and its effects on learning motivation (Prasetyanti, 2016). However, bibliometric analysis related to PBL in laboratory practical activities is still scarce, especially in the field of biology. Bibliometric analysis of a number of articles indexed WoS can mapping a large number of publications and can identify possible gaps in the field of Biochemistry education (Barbosa & Galembeck, 2022) This article aims to provide a detailed explanation through bibliometric analysis of existing literature on PBL related to laboratory practical activities. Several pieces of literature were obtained from the Scopus database using specific criteria such as time, the countries of article origin, and distribution patterns.

This study aims to address the following questions: the first is How does the number of publications vary each year based on the keywords used?; the second one is Which countries are the most productive in their publications in international journals indexed by Scopus during the period 2015-2024?; the third is What is the Co-occurrence overview of PBL related to laboratory practical activities?; and the last one is What is the Overlay Visualization overview over the last 3 years (2021-2023)?

Method

This study represents a bibliometric analysis aiming to provide an overview of the research trends related to the application of Problem-Based Learning (PBL) in laboratory practical activities. It encompasses aspects such as authors, article titles, and the journals publishing them. Literature searches were conducted using the Scopus database, starting in November 2023. Data collection involved the use of the keyword "PBL in Laboratory Activities," resulting in 961 documents. Subsequently, data were filtered based on journal types, article titles, and publications up to the latest detection date (article publication time: 2014-2023). The search was conducted in English. Based on the filtered search results, 453 documents were obtained. This research was carried out in five stages, as indicated in Figure 1. The next step involves analyzing the obtained data using the VOSviewer application's co-occurrence feature to analyze the number of articles, publication years, and

the top 10 countries with the highest publications. These steps are based on references (Misbah, Hamidah, Sriyati, & Samsudin, 2022); (Misbah, Purwasih, et al., 2022).

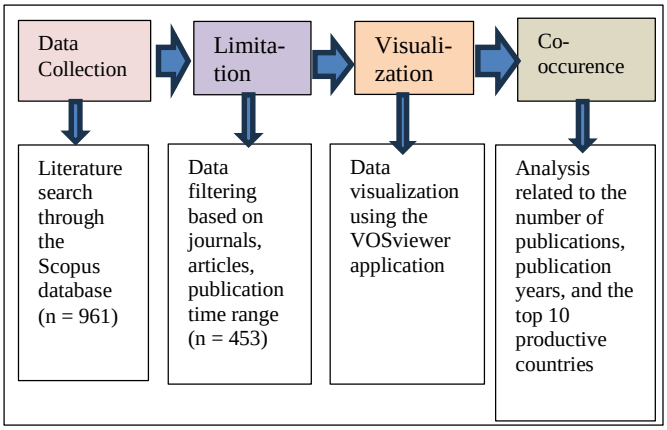

Figure 1. Steps of the research

Result and Discussion

Number of Publications on PBL and Laboratory Activities from 2014 to 2023

The number of publications on the topic of PBL in laboratory practical activities from 2015 to 2023 is presented in Figure 2.

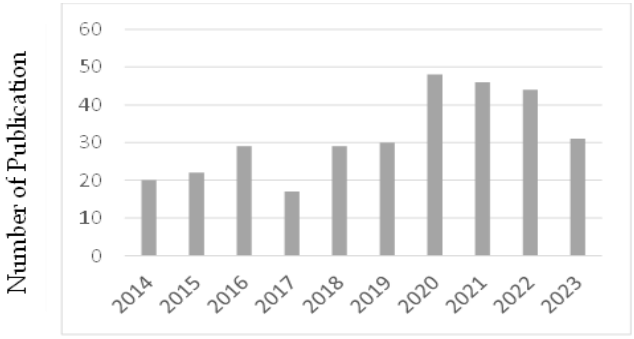

Figure 2. Number of Publication by Year

The figure illustrates an increasing trend in publications from 2015 to 2022, followed by a decrease in 2023. This decline is predicted to be temporary and may be countered with research on PBL, which has the potential to enhance student learning outcomes and critical thinking (Utomo, Hasruddin, Murad, 2020), develop 21st-century skills in students (Getingoz, 2023), and accommodate learners' scientific processes (Gallagher, et al, 2023).

Analysis of Publications Based on Country Productivity

The publications utilized in this research are Scopus-indexed journals. Data on the 10 most productive countries in publishing their research findings were obtained, with the United States being the most prolific country, contributing 194 publications in Scopus-indexed journals. Spain takes the second position with 26 documents, followed by Australia with 22 documents. Unfortunately, Indonesia does not rank among the top 10 most productive countries in generating internationally scaled publications. Indonesia is placed at the 13th position with only 8 publications on an international scale. The United States holds the first position as the country publishing the most articles on PBL related to laboratory activities, including the impact of PBL in health profession education (Waite, Smith, McGiness, 2020).

PBL methodology can motivate active student participation in problem-solving (Salgado-Chavarría, Palacios-Alquisira, 2021). The highest interest, intrinsic motivation, and behavioral involvement are found in groups solving problems in the laboratory setting (Erickson, Marks, Karcher, 2020). The United States also holds the top position in the topic of Critical Thinking in Science Education (Misbah, et al., 2022).

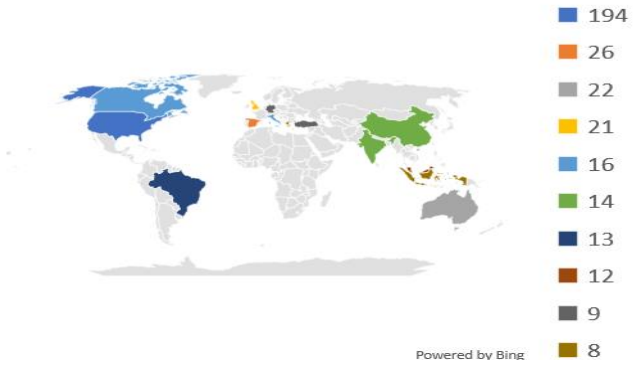

Figure 3. Number of Publication by Country

Visualization and Co-occurence Research Trend

Based on the co-occurrence analysis using VOSviewer and the keyword "PBL in laboratory activities," six publication clusters were identified, as shown in Figure 4. Within each cluster, there are publications with specific keywords, as indicated in Table 1.

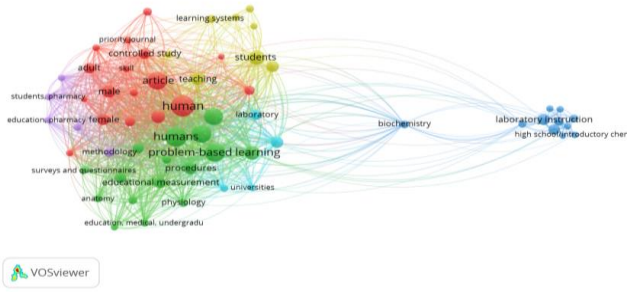

Figure 4. Network Visualization of PBL and Laboratory activities

The network illustrates the diversity of topics in research related to PBL and laboratory practical guides.

Table 1. Research Topics on Each Cluster

Cluster	Num-ber of item	Keywords
Red	17	Adult, article, contrlled study, decision making, female, human, human experiment, learning machine learning, major clinical study, male, perception, priority journal, problem solving, questionnaire, skill, young adult
Green	16	Active learning, anatomy, curriculum, education, education, medical, undergaduate, eduacional measurement, humans, medical eduacion, medical student, physiology, problem based learning, problem-based learning, procedurs, psychology, student, medical, surveys andd questionnaire
Dark Blue	11	Biochemistry, bollaborative/ cooperative, first-year undergraduate, hands-on learning, hig school /introduction, inquiry-based/discovery, laboratory instruction, organic chemistry, problem solving/decision, second-year undergraduate, upper-division undergraduate
Yellow	8	Curricula, e-learning, engineering education, laboratories, learning systems, simulation, students, teaching
Purple	5	Clinical competence, education, pharmacy, methodology, pharmacy student, students pharmacy
Light Blue	4	Laboratory, student, universities, university

The most prominent clusters are in red and green. This display indicates a strong research focus on topics like. problem-based learning (Waite, et al, 2020); Achappa; Patil; Hombalimath; Shet, 2020) related to instructional models, active learning, learners, biochemistry (Li; Jia; Chi; Liu, 2020), procedures, problem-solving, and measurement in higher education, and physiology (Cardozo; Castro; Guimarães; Gutierrez; Montrezor; Marcondes, 2020)The red cluster includes machine learning; where problem solving is by developing new water treatment products using agricultural waste through project-based learning (Oyewo; Ramaila; Mavuru, 2022). The yellow cluster highlights curriculum topics (Durand, et al, 2019), engineeing education (Persano; Scardulla; D'Acquisto; Pizzolato, 2023); Jabarullah; Hussain, 2019) learning systems, and teaching (Costantino, Barlocco, 2019), laboratory of technical education (Pardo, 2022). Light blue clusters are interconnected with laboratory-related topics (Stomberg, Walder, Darner, 2018); (Knapp S., 2016); Budner D.; Simpson B., 2018), students (Blumer L.S.; Beck C.W., 2019), problem-based learning (Erickson, et al, 2020), problem-solving (Caldas, et al, 2020), and biochemistry (Thibaut, Schroeder, 2020). The dark blue cluster is related to universities and laboratories (Demers, Fung-A-Fat J, Andreatta, Kerr, Xu, 2022; Çeliker, 2021). The purple cluster related to the topics of Clinical competence, education, pharmacy students (Powers, et al, 2019; Caldas, et al, 2020).

Overlay Visualization of PBL in Laboratory Activities

Based on the Overlay Visualization, the keywords "PBL and Laboratory Instruction" are associated with research topics on PBL, laboratory work procedures, biochemistry, experiments, involving both young and adult individuals, from secondary education to higher education. Laboratory activities most commonly using PBL are related to biochemistry topics, learning, and are also connected to the learners (Figure 5). The visualization also depicts that laboratory activities are closely related to inquiry-based/discovery learning. This result suggests that bibliometric analysis is effective in visualizing current literature that can be utilized for ongoing research.

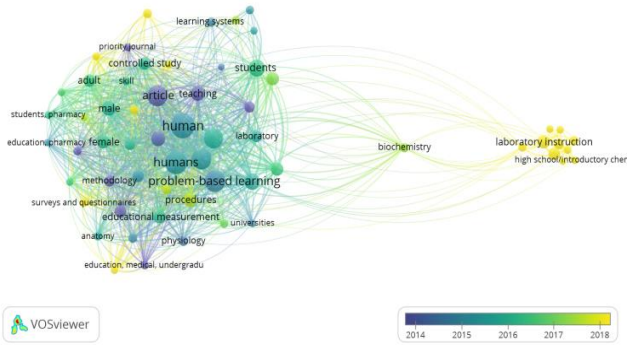

Figure 5. The Overlay Visualization of PBL research

The strongest topics related to laboratory instruction are inquiry-based/discovery learning (Vardar-Ulu.D, 2014), second-year undergraduate, and biochemistry (Nag, 2023). However, these keywords are also linked to earlier topics such as problem-solving, decision-making, and curriculum in the 2014-2016 timeframe (Figure 6).

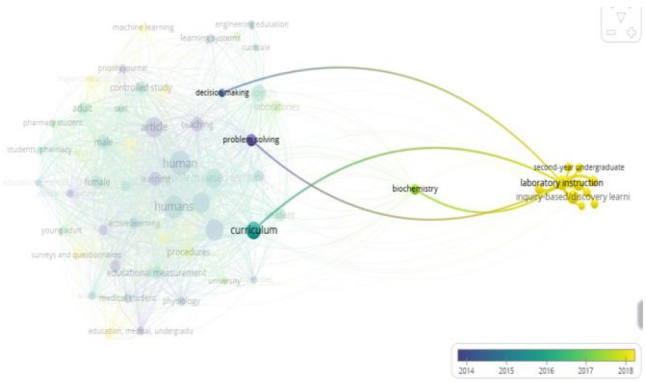

Figure 6. Visualization of the strengths of the topics research

Conclusion

Based on the bibliometric analysis using the VOSviewer application conducted on PBL and its relation to laboratory activities, it can be concluded that: 1) The number of publication articles based on keywords is 961 documents, filtered down to 453 documents, 2) The country contributing the most to related article publications is the USA with 194 documents, 3) Based on Co-occurrence analysis using the VOSviewer application, article topics are divided into 6 clusters, and 4) Overlay Visualization indicates that articles on laboratory activities tend to focus on the learning system, related to second-year undergraduate students, curriculum, and problem-solving.

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Author Contributions

This bibliometric analysis research on the integration of PBL with laboratory activities is an idea from the first author who was inspired by the results of discussions with the second and third authors. Metadata was obtained based on instructions and guidance by the second and third authors, then data interpretation was carried out jointly with the fourth author. Formal Analysis (data analysis and synthesis) also involves all of the authors; where data on a number of articles obtained from the Scopus database is sorted, studied, then analyzed based on the number, year and distribution of publications of the articles studied. Presentation of data and writing of the original draft of the article was carried out by the first author, which was then consulted and validated and supervised by the second, third and fourth authors. All authors have read and approved the manuscript before publication.

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Conflicts of Interest

The authors hereby declares that there is no conflict of interest. Whatever research results are presented are the result of a study of existing data. The authors agreed to publish the results as a manifestation of scientific responsibility

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