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Research Trend of PBL and PjBL in Bibliometric Analysis: Implications for a Better Future of Physics Education

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ABSTRACT

This research investigates the growing research trends surrounding the application of Problem-Based Learning (PBL) and Project-Based Learning (PjBL) in the Physics Education domain. Using a bibliometric analysis approach, data sourced from the Scopus database yielded 89 related documents. The findings revealed a significant surge of scholarly interest in the implementation of PBL and PjBL in Physics Education over the past decade, indicating a growing area for further exploration. In particular, there is a growing trend to integrate PBL and PjBL methodologies with STEM education, as this incorporation has shown promise in enhancing critical thinking, problem-solving abilities, and student engagement. However, it's important to note that this researh was constrained by its dependence on a sole database, namely Scopus, for the collection of data. Future research efforts in PBL and PjBL in Physics Education are encouraged to utilise diverse databases to ensure comprehensive coverage and analysis.

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INTRODUCTION

Problem-based learning (PBL) and project-based learning (PjBL) have taken center stage in the evolution of physics education. PBL emphasizes learning through solving real problems (Samadun & Dwikoranto, 2022), while PjBL leads to the exploration and application of physics concepts in projects that require problem solving (Lestari et al., 2022; Maysyaroh & Dwikoranto, 2021; Putri & Dwikoranto, 2022). In physics education, PBL and PjBL offer a number of important advantages. First, they provide a more engaging and contextualized learning experience for students. By applying physics concepts in real-world situations, students can see the direct relevance of what they are learning (Dewi & Primayana, 2019), encouraging deeper engagement and higher motivation in the learning process (Rahmawati et al., 2022). This learning model can develop crucial 21st century skills, such as problem solving, creativity, collaboration, and critical thinking (Rochmawati et al., 2019; Yulianto et al., 2019). Students not only understand physics concepts, but also hone the ability to apply this knowledge in a real-world context.

Within the framework of Merdeka Belajar curriculum, where emphasis is placed on adaptive, collaborative and responsive learning, PBL and PjBL offer suitable solutions. Both learning models support a curriculum that prioritizes relevant learning experiences, as well as providing opportunities for students to develop the abilities they need in the modern era (Diana & Sukma, 2021; Sukackė et al., 2022). Through this approach, physics learning does not only aim to convey knowledge, but also to prepare students to become independent learners and problem solvers who are responsive to the demands of the times (Santyasa et al., 2020; Sukackė et al., 2022). With a focus on Merdeka Belajar, the integration of PBL and PjBL in the physics education curriculum is expected to provide a strong foundation for 21st century physics education, offering students

a deep understanding of physics concepts as well as skills that are relevant and necessary in modern society. This is also in line with Merdeka Belajar's mission to create a learning environment that is responsive, inclusive, and empowers students to become active agents of change in society (Rochmat et al., 2023).

Physics education in the 21st century has faced increasingly complex demands. Changes in technology, social dynamics, and economic demands have created the need for a learning approach that is more adaptive and oriented towards the application of knowledge in real contexts (Fazey et al., 2020). This requires physics education that not only teaches theoretical concepts, but also encourages students to integrate that knowledge into real solutions, which are in line with the demands of the times. In this regard, PBL and PjBL offer a breakthrough in learning approaches. They enable students to learn physics more deeply, in a way that not only strengthens theoretical understanding, but also develops practical skills that are relevant and necessary in modern society (Miller & Krajcik, 2019; Sukackė et al., 2022). These include skills such as problem solving, critical thinking, communication skills, and effective collaboration.

Over time, there has been a significant increase in research related to PBL and PjBL in physics education. Research related to PBL and PjBL learning models is important to do, because learning models in schools can affect students' abilities. Therefore, it is important to explore research trends related to PBL and PjBL learning models, especially in physics education by conducting a bibliometric analysis to understand the development of research on the topic. This can help academics, researchers, and teachers to understand the trends and research topics related to learning models so that they can develop more effective strategies and applications in the use of these learning models in schools.

Bibliometric analysis serves as a methodological approach employed to recognize prevailing trends in research, assess scholars' contributions, and pinpoint the focal areas of investigation within a particular academic discipline (Lin et al., 2022). Bibliometric analysis offers valuable gap research to understand publication trends, identify frequently published journals, assess author productivity, and explore prevalent research topics within the domains of PBL and PjBL methodologies (Gao et al., 2021). However, currently there are still not many research trends on PBL and PjBL models in schools, especially in physics education. Therefore, research on the utilization of PBL and PjBL is an important novelty to be researched. Through this research, it is expected to better understand the use of PBL and PjBL models in schools and how these methods can increase students' learning motivation, independence, problem solving and critical thinking. The insights gleaned from bibliometric analysis hold promise for the educational community, particularly in the field of physics education, by facilitating the optimization of PBL and PjBL implementation strategies in forthcoming endeavors. Moreover, bibliometric analysis can illuminate prospective research trajectories, enabling researchers and educators to pinpoint areas for further exploration and address existing knowledge lacunae effectively (Tlili et al., 2022).

By conducting a bibliometric analysis, this article aims to analyze research trends related to PBL and PjBL in physics education. The bibliometric analysis will provide a deep insight into the extent to which PBL and PjBL concepts have been applied, studied, and adopted in the realm of physics education. In addition, this article also aims to evaluate the impact and implications of these research trends on the future of physics education, including potential improvements and adjustments that can be made in the learning process.

The implication of this research trend is that it is important to shape a future view of physics education that is more adaptive, responsive and effective. By considering the future direction of physics education, the integration of PBL and PjBL in the curriculum can provide a strong foundation for creating a generation that not only understands physics, but is also able to apply it in various life contexts. This will help create learners who are ready to face the challenges of an ever-changing and evolving era.

RESEARCH METHOD

In this research, bibliometric analysis was performed utilizing quantitative techniques that concentrate on international journal publications. The Scopus database served as the primary source of literature indexed by numerous reputable international publishers. The objective of this bibliometric analysis is to offer a comprehensive insight into various disciplines and to visualize publication trends and contributions of articles to knowledge advancement (Guo et al., 2019; Yulianingsih et al., 2020).

In a search using the Scopus database with the keywords "(PBL OR PjBL AND in AND physics AND education)", 89 articles were found which became the source of data for this researh. After the data was collected, it was processed using Ms Excel and VosViewer to produce bibliometric mapping. Through this analysis, it is expected to gain an understanding of innovations and trends in research, which will guide researchers and educators in identifying areas that still require further research for future knowledge development (Dwikoranto et al., 2023).

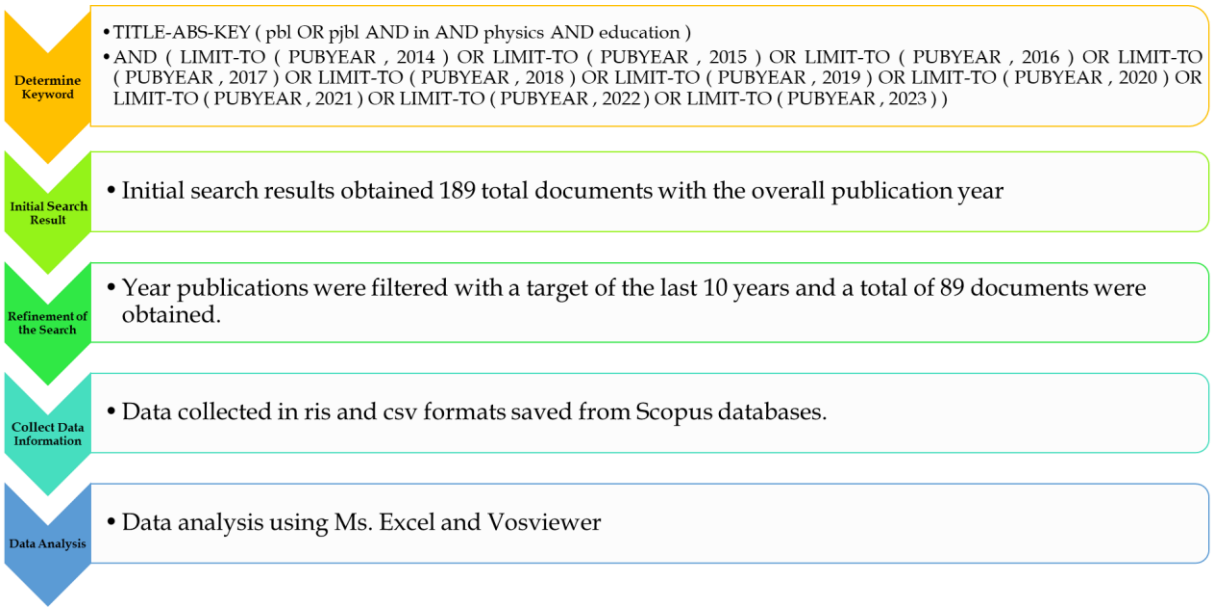


Figure 1. Steps in conducting bibliometric analysis
(Dawana et al., 2022a; Dawana et al., 2022b)

Figure 2 shows the steps in analysing data using the bibliometric analysis method. This approach uses Vosviewer software to illustrate research trends by visualising co-occurrence relationships between authors, relevant documents and keywords related to the research topic (Dawana, Setyarsih, et al., 2022). This research involved analysis using network visualisation and overlay techniques. This method was then used to explore and understand the correlation between PBL and PPA models in the realm of physics education. It is hoped that through this research, a deeper understanding of how the utilisation of PBL and PjBL models can improve learning in the school environment can be obtained, as well as providing valuable insights for the development of future learning models.

RESULTS AND DISCUSSION

From the search results in the Scopus database using the keywords "PBL and PjBL and Physics" which resulted in a total of 189 documents, then filtered with the last 10 years of publication resulting in a total of 89 documents. Next, the files were extracted in (.csv) and (.ris) formats, and analysed using MS Excel and VosViewer software. This process resulted in outputs that were systematically organised to determine relative meaningfulness and identify the most relevant keywords, as shown in Table 1.

Table 1. Top 10 documents with the highest relevance to the research topic

Result Number	Authors	Year	Source	Cited	Ref
1	Arnida N. S.; Wibowo F. C.	2022	Journal of Physics: Conference Series	0	(Arnida & Wibowo, 2022)
2	Chng E.; Yew E. H. J.; Schmidt H. G.	2015	Advances in Health Sciences Education	27	(Chng et al., 2015)
3	Johnson B.; Ulseth R.; Smith C.; Fox D.	2015	Proceedings - Frontiers in Education Conference, FIE	26	(Johnson et al., 2015)
4	Sulaiman F.; Rosales J. J.; Kyung L. J.	2023	Journal of Baltic Science Education	2	(Sulaiman et al., 2023)
5	Lai C. S.; Alias M.; Rosli D. I.; Foong L. M.	2017	Proceedings of the 2017 IEEE 9th International Conference on Engineering Education, IEEE ICEED 2017	1	(Lai et al., 2017)
6	Shishigu A.; Hailu A.; Anibo Z.	2018	Eurasia Journal of Mathematics, Science and Technology Education	32	(Shishigu et al., 2017)
7	Kurniati R. D.; Andra D.; Wayan Distrik I.	2021	IOP Conference Series: Earth and Environmental Science	0	(Kurniati et al., 2021)
8	Vesikivi P.; Hjort P.; Lakkala M.; Holvikivi J.; Lukkarinen S.	2015	Proceedings of the 43rd SEFI Annual Conference 2015 - Diversity in Engineering Education: An Opportunity to Face the New Trends of Engineering, SEFI 2015	5	(Vesikivi et al., 2015)
9	Suhartono; Cari; Sarwanto; Susanti E.; Fatmawati S.	2023	Eurasia Journal of Mathematics, Science and Technology Education	0	(Susanti & Fatmawati, 2023)
10	Suhirman; Prayogi S.	2023	Humanities and Social Sciences Letters	0	(Prayogi, 2023)

From the information presented in Table 1 regarding the top ten articles retrieved from the Scopus database, it can be inferred that the article with the highest relevance holds the first position. These ten articles play a crucial role in scrutinizing the utilization of Problem Based Learning and Project Based Learning (PBL and PjBL) within the domain of Physics education

Based on the research that has been conducted on these ten articles, the results show that PBL learning can affect interest, and increase learning achievement along with students, PBL can also be integrated in STEM learning to improve critical thinking, and problem solving, then PBL can also be integrated with virtual practicum learning so that it can improve students' critical thinking skills. PjBL learning can be applied to increase students' independence and students' skills (Diana & Sukma, 2021). Some PBL learning can be integrated with e-learning-based technology and learning media such as e-modules or e-books (Mahmudah et al., 2022). Technology integration in PBL, such as e-learning, e-modules, or e-books, also proves its ability to improve learners' skills, provide wider access, and enrich learners' learning experience (Kiet, 2023). All of which shows that PBL and PjBL, when well integrated and supported by appropriate technology, can provide significant benefits in skill development as well as student learning outcomes in various educational domains.

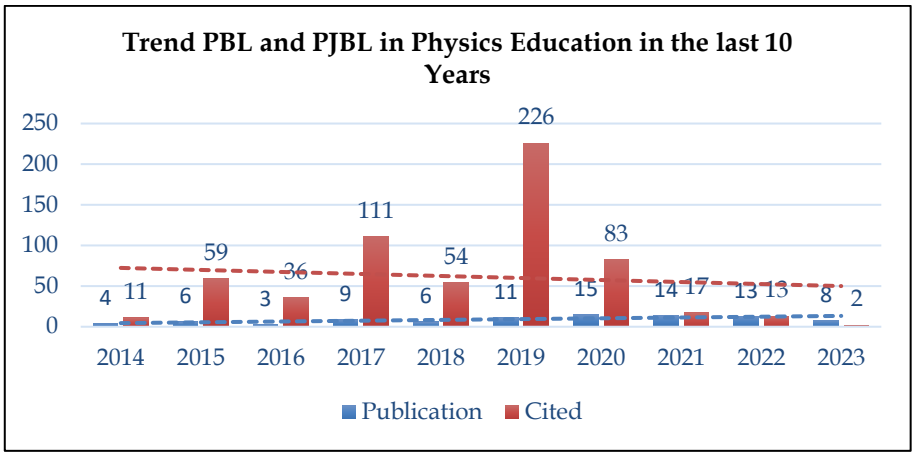


Figure 2. Number of Scopus Database publications and cited of PBL and PJBL physics education in the last 10 years

Figure 2 shows the trend of PBL and PjBL research publications in physics education on the Scopus database which is an important indicator in identifying developments and challenges in physics learning. Based on the graph, it is known that the number of publications tends to increase from year to year, and reached a peak in 2020. Citations also increased generally from year to year, although there were fluctuations in 2021 to 2023.

This graph shows a clear trend in the use of PBL and PjBL in physics education, where the use of PBL and PjBL increases exponentially from year to year. This shows that the use of PBL and PjBL is increasingly important in Physics education which has begun to use learning models as an effort to improve the quality of learning and face the challenges of the 21st century, as stated by (Puspitasari, 2020; Sebatana & Dudu, 2022; Tan, 2021). The use of PBL and PjBL offers successful 21st century learning. In facing increasingly complex future challenges, physics education is required to prepare students with skills that go beyond conceptual understanding. Learning models such as PBL and PjBL offer approaches that encourage students to solve problems independently, collaborate, think critically, and adapt to real-world contexts (Almulla, 2020; Rahmania, 2021; Sukackė et al., 2022). The interactive nature of these two learning models also enriches students' learning experience, providing space for deeper exploration of physics concepts in a situation that is close to the real situation. Thus, the use of PBL and PjBL in physics education not only improves the quality of learning by providing a more thorough understanding, but also produces students who are ready to face challenges and innovate in the 21st century.

Subsequently, bibliometric analysis mapping was performed using Vosviewer software, and the results were represented through network analysis focusing on the keywords PBL and PjBL in the field of physics education. The outcomes of this investigation are illustrated in Figure 3 below.

The results of the mapping of research trends on PBL and PjBL in physics education have been presented in Figure 3. The purpose of the mapping is to identify emerging research based on observed trends. The results show that there are 8 clusters of PBL and PjBL in the context of physics education. The first cluster, marked in red (n = 19), focuses on developing PBL learning models, enhancing students' skills, and developing learning systems, among other aspects. Next, the green-coloured cluster (n = 16) paid more attention to the learning materials used. The next cluster, dark blue (n = 14), highlights learning integration such as the implementation of STEM learning models and the use of learning media such as augmented reality. The yellow cluster (n = 13) puts more emphasis on the outcomes of the learning curriculum. Clusters in purple (n = 9), focus on PjBL model, online learning, and e-learning etc. The light blue cluster (n = 12), focuses on the integration of learning with technology, such as e-modules, phet, e-handouts. The orange cluster (n = 9), focuses on learning activities and engineering education. Finally, the brown cluster

(n = 3) focuses on the application of PjBL for critical thinking which has more than a few keyword occurrences and research focus.

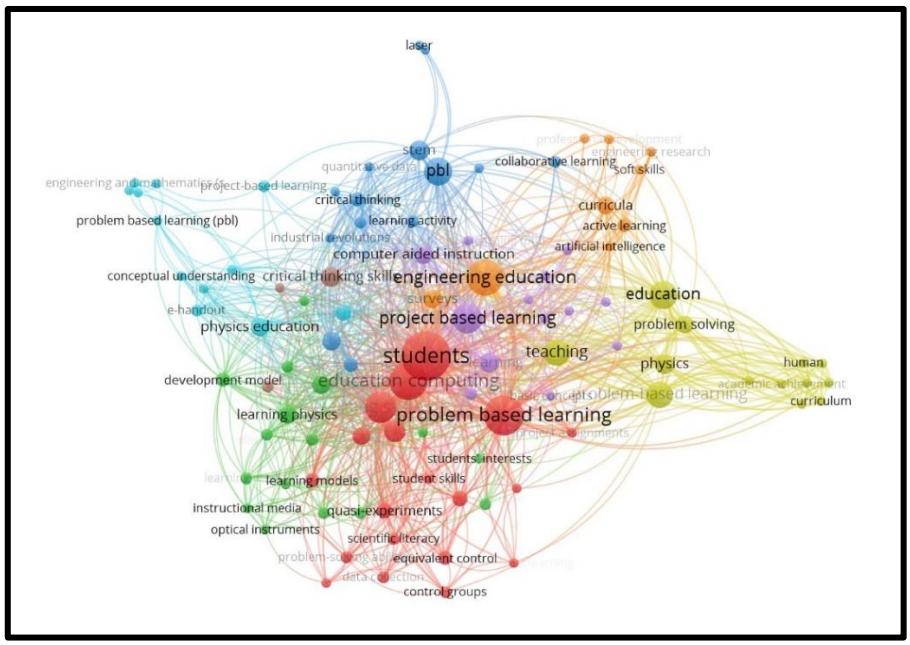


Figure 3. Mapping on PBL and PJBL in physics education on the Scopus Database

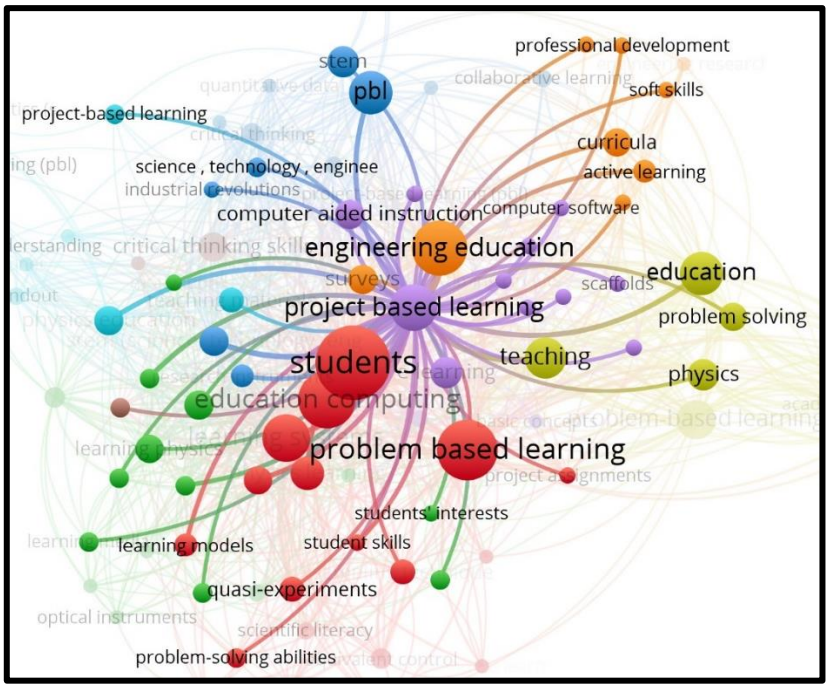


Figure 4. Keyword mapping results with topics PjBL

Figure 4, an illustration of the outcomes from a detailed keyword mapping focusing on PjBL in Physics Education is presented. This visualization indicates the promising prospects for further exploration of PjBL in Physics Education due to its extensive scope and adaptable nature. PjBL correlates with student interest, problem solving, soft skills and the PjBL model can be integrated with STEM. In this case, the PjBL model greatly contributes to physics education. Based on research from (Adriyawati et al., 2020; Chang & Chen, 2023; Hussein, 2021) the PjBL model can attract student interest, because PjBL, with its approach that emphasizes real projects and practical applications, often triggers student interest. These projects connect the subject matter to relevant real-world situations, thus increasing students' interest in the subject being studied. PjBL

encourages students to solve problems in the context of the project they are working on (Almulla, 2020; Miller & Krajcik, 2019). In this process, they have to face complex problems, find solutions, and apply them practically, which will improve problem-solving skills. Through working on projects, students are exposed to situations where they have to collaborate, communicate, organize time, and manage projects (Belwal et al., 2020). This enriches the development of soft skills, such as communication skills, leadership, cooperation, and independence (Dogara et al., 2020). The PjBL model can be integrated with STEM. Physics projects that focus on science, technology, engineering, and math can provide a more thorough and applicable understanding of concepts in these fields. The integration of PjBL with STEM provides opportunities for students to learn holistically, engaging learners in projects that span multiple disciplines (Wilson, 2021). This not only provides a deeper understanding, but also allows students to see the interconnections between different disciplines and how they are applied in real-world situations.

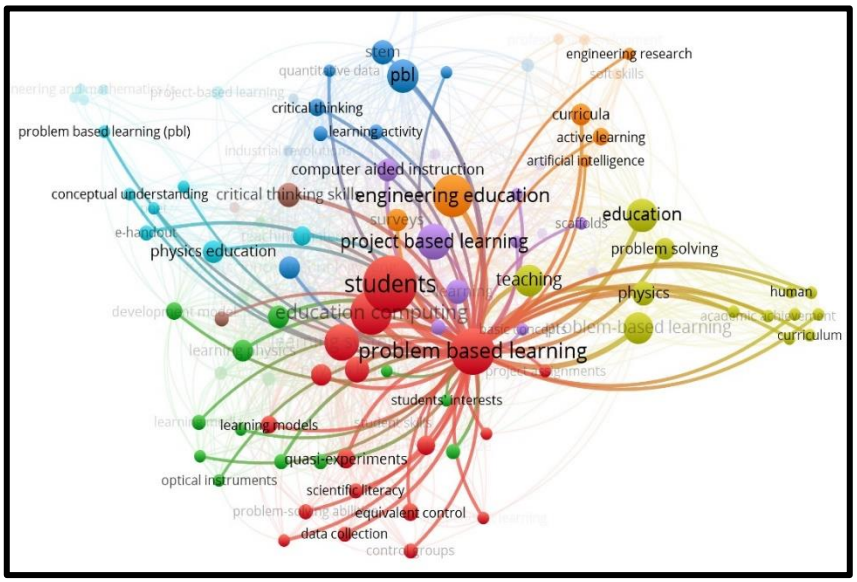


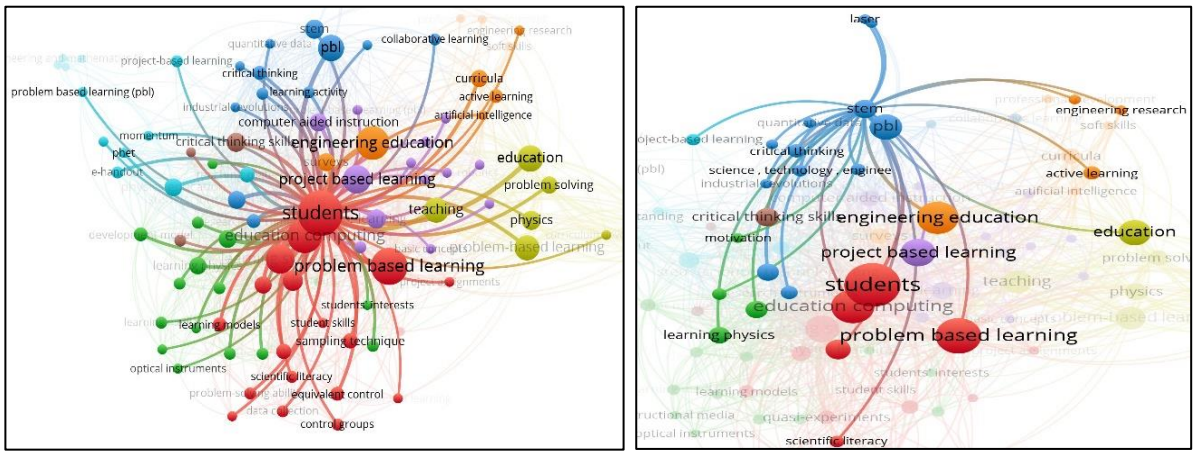
Figure 5. Keyword mapping results with topics PBL

Figure 5 in this figure shows an example of more specific keyword mapping results on PBL in Physics Education. In Figure 5, it can be seen that the trend of PBL in Physics Education has great potential to be further explored because the topic has a wide scope and is flexible in its application. PBL correlates with conceptual understanding, scientific literacy, problem solving, critical thinking and e-learning, then PBL can also be integrated with STEM. In this case, the PBL model greatly contributes to physics education.

This is in accordance with research by (Fidan & Tuncel, 2019; Zhao et al., 2020) encourages deep conceptual understanding. Through real-world problem solving, students do not just memorize facts but really understand 'why' and 'how' physics concepts work in a practical context. Research by (Nurtanto et al., 2020) said that PBL helps in developing scientific literacy. Students engage in observation, experimentation, and evidence-based reasoning, which are key elements of scientific literacy (Sengul, 2019). PBL inherently involves students in problem solving that requires critical thinking. Learners must analyze situations, formulate solutions, and evaluate the most appropriate approach, strengthening their critical thinking skills. PBL can be integrated with learning technology, including e-learning. The use of technology in supporting PBL provides access to wider resources, enriches the learning experience, and facilitates collaboration on digital platforms (Tsalapatas et al., 2021). Examples are the use of E-Books, E-Modules, and Augmented Reality.

PBL can be highly integrated with STEM because it brings physics theories closer to real-world applications in various disciplines. This allows students to see the connections between physics and science, technology, engineering and math, which can enhance their understanding

of the interconnection of concepts in STEM. With a focus on problem solving and deep conceptual understanding, PBL provides a strong foundation for the development of relevant skills and knowledge in physics as well as other STEM disciplines (Rosales et al., 2020; Saleh et al., 2020).



(a) (b)

Figure 6. More specific keyword mapping results with topics a) Student, and b) STEM

Figure 6(a) shows that the research trend of PBL and PjBL is very supportive in improving learners' skills. Figure 6(b) shows that STEM can be interrelated with PBL and PjBL models and learner learning outcomes such as scientific literacy, critical thinking, motivation, and active learning. This means that PBL and PjBL models have great potential to be further explored as they have a wide range of topics and are flexible in their application (Dwikoranto et al., 2023).

PBL and PjBL are well-regarded learning models in physics education as they offer a number of advantages and benefits relevant to the physics learning context. Both present a real-world context to students with an emphasis on solving relevant physics problems and projects that enable the application of physics concepts in practical situations. Through students' active engagement in these projects, their understanding of physics concepts becomes deeper and more practical. In addition, both PBL and PjBL have a positive impact on the development of students' critical thinking skills, as they have to analyze, formulate hypotheses, and find solutions to complex physics problems (Nur'aini et al., 2022; Suastra et al., 2019).

Both learning models also encourage students' collaboration, communication and independence skills, which are important aspects in the field of science and technology. Technology integration in PBL and PjBL, such as the use of e-modules or e-books, enriches students' learning experience, expands access to learning resources, and helps students prepare for real-world demands with strong physics skills and understanding (Batubara et al., 2023). All these make PBL and PjBL as effective and powerful learning models in shaping students' deep understanding, skills, and readiness in physics.

Recommendations for future research are to integrate PBL and PjBL learning models with STEM in physics learning. Although stem integration has been applied to both models, the bibliometric relationship cycle is still relatively small and researchers still contribute less to research in the field of STEM. So this will be an opportunity for further research to increase physics education publications on PBL and PjBL learning models (Dawana & Dwikoranto, 2024).

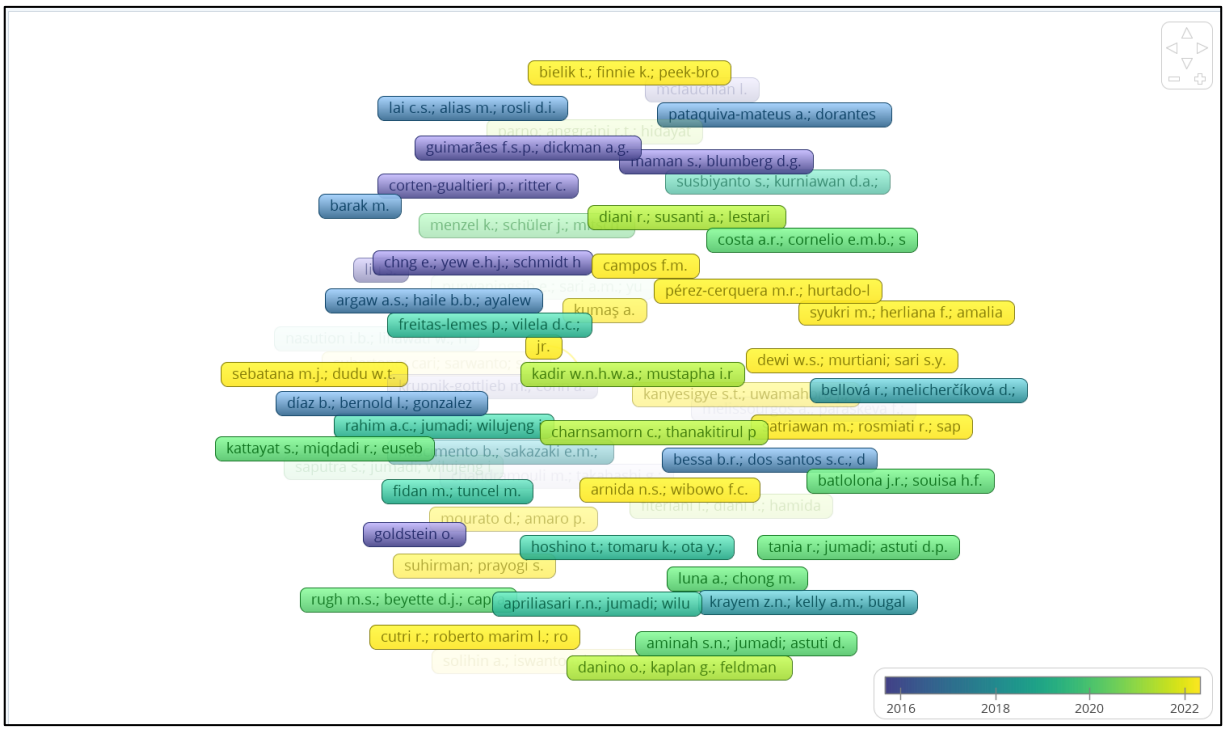


Figure 7. Highest author visualization and overall author visualization in PBL and PJBL research

Based on Figure 7, this is the result of the author's visualization which is not limited by interconnections. It was found that there were 89 authors whose connections were not limited by a threshold, thus allowing for a comprehensive representation of the data. In 2019-2022 is a cluster period of years for the publication of the latest research in the field of PBL and PjBL (Tan, 2021). While in 2016-2018 with dark blue marks are previous research publications (Belwal et al, 2020; Batubara et al, 2023).

The limitation of this research lies in the selection of databases that are limited to Scopus, so that only data from Scopus can be considered in visualisation (Dawana et al, 2022; Zhao et al, 2020). To overcome this, it is suggested that future research on PBL and PjBL trends consider using broader data sources such as Google Scholar (Santyasa et al, 2020), By doing so, it will be possible to gain a more comprehensive understanding of research trends involving multiple data sources.

CONCLUSION

Based on the results of the bibliometric analysis and literature review, several significant findings were identified. Publication trends regarding PBL and PjBL in the context of Physics education show a significant increase, and have the potential to be further explored in future research. Great potential was seen in topics related to PBL and PjBL in Physics education, encouraging further research in the future. Through research mapping, it was revealed that the main focus of research on PBL and PjBL in Physics education includes: 1) Integration of technology in learning, such as e-learning and e-modules; and 2) The application of STEM in learning to improve learners' skills.

The implications of these findings include the identification of novelty in PBL and PjBL learning in Physics education, providing a foundation for future research. The findings also enrich knowledge in this field and provide references for further research by applying PBL and PjBL models in the context of Physics education. This researh also demarcates future research trends, as well as provides recommendations for expanding data sources beyond Scopus in future research on PBL and PjBL in education.

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