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Exploring The Role of Media in Enhancing Problem-Based Learning in Physics: A Systematic Literature Review

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Abstract

Problem-Based Learning (PBL) is a learner-centred model that focuses on solving problems to train students in addressing challenges they face through real-world problem exploration. This review aims to identify research trends, methodologies, physics topics, associated variables, and outcomes in the field. The systematic literature review followed the PRISMA framework, encompassing the stages of identification, screening, eligibility, and inclusion. A total of 67 articles were analyzed. Articles (2020–2024) were selected using Publish or Perish, Scopus, and SINTA, focusing on PBL in physics with media integration and focusing on research trends, methodologies, topics, variables, and outcomes. Eligibility criteria included international language and publication in 2014–2024, while data was analyzed using Excel and visualized with Tableau. Problem-based learning research (2014–2024) focuses on Indonesia, with 2023 as the peak year. Mechanical physics and critical thinking dominate topics and variables, mainly using quantitative methods. Video multimedia is the most common media, highlighting the need to explore innovative media integration in problem-based learning further. This SLR highlights key research trends and gaps, guiding future studies to enhance problem-based learning through effective media use.

Keywords: problem-based learning, media, learning physics, physics.

INTRODUCTION

The Problem-Based learning model is a learning model that encourages learners to conduct investigations or explorations based on authentic problems (Suhirman & Prayogi, 2023). PBL is a learner-centred learning approach involving collaborative learning where learners work together to solve open problems. PBL serves as a means for active learning, with core principles that include learner independence and self-direction, group-based learning, and the teacher acting as a facilitator, with all groups participating equally (Gumisirizah, Muwonge, & Nzabahimana, 2024). PBL is one of the effective ways to teach physics when video-integrated learning is used in public and private schools, so teachers are recommended to apply it in their daily teaching activities (Gumisirizah, Muwonge, & Nzabahimana, 2024). Problem-based learning (PBL) is a learning model that focuses on solving real problems to train students to solve the problems they face. PBL is a learner-oriented learning system relevant to the Indonesian curriculum (Prahani et al., 2022). PBL (Problem-Based Learning) is a teaching method in which learners solve problems based on real-life situations. In PBL, learners engage in interesting and relevant intellectual inquiry based on real cases

(Kanyesigye, Uwamahoro, & Kemeza, 2022). PBL (Problem-Based Learning) is a learning model designed to improve learners' critical thinking skills, which utilizes problems as a stimulus for face-to-face and online learning (Sujanem & Suwindra, 2023). PBL, or Problem-Based Learning, is a learning model that stimulates learners with contextual problems taken from everyday life and aims to improve learners' understanding of the concepts taught, such as in physics, by linking them to local wisdom or community traditions (Rahmasari & Kuswanto, 2023).

The problems raised in the study and study objectives that provide solutions to these problems from some of these articles that examine physics learning models are: first, a study conducted by (Gumisirizah, Muwonge,&Nzabahimana, 2024) on low academic achievement in physics subjects in secondary schools, both in government and private schools, this is caused by the lack of effective learning resources and inadequate teaching methods, so PBL is integrated with videos to help students learn simple aircraft material. Second, a study conducted by (Suhirman & Prayogi, 2023) also shows the low critical thinking skills (CT) of students in Indonesia, which is a significant concern in achieving national education standards. The "Freedom to Learn" program introduced in Indonesia aims to develop students' CT skills using a problem-based learning (PBL) model. The challenge arises when learning during the COVID-19 pandemic is carried out remotely, so the study objective is to train students' CT skills through distance learning. In addition, students are less motivated in science subjects with an e-learning system using PhET simulations. Third, a study conducted by (Kanyesigye et al., 2022) also explains the difficulties faced by Ugandan students in understanding the concept of mechanical waves; the lack of understanding of concepts is due to the teaching model, and a learning model is needed to help students develop knowledge, one of which is PBL.

PBL research as a learning approach is conducted by (Gumisirizah, Muwonge,& Nzabahimana, 2024) focuses on improving students' problem-solving skills through the Problem-Based Learning (PBL) approach in teaching physics, especially on simple aircraft physics material, which aims to test whether or not there is a significant increase in students' problem-solving skills after the application of the PBL method compared to traditional content-based teaching methods.

In research that integrates the model with PBL, the problems found in the 3 studies include: first, research conducted by (Prahani et al., 2022) on how to develop and implement a Problem-Based Learning (PBL) based learning module on magnetic force and magnetic field material that is effective for improving students' problem-solving skills, and this study aims to identify the obstacles faced by students in learning physics during online learning and how PBL can be a solution to overcome these problems. Second, (Akhatayeva et al., 2024; Nyirahabimana et al., 2024) researched how to develop effective problem-based interactive e-modules to improve students' critical thinking skills in physics learning. This research aims to overcome the limitations of traditional teaching methods that can less optimally improve students' critical thinking skills. The research problem in this article is to examine the effectiveness of using a physics pocketbook that integrates augmented reality (AR) with the local wisdom of catapults in improving high school students' mathematical and graphic representation skills. This study aims to see whether this approach can significantly contribute to physics learning, especially in elasticity material.

Another problem found from the results of the journal analysis is that some students still find it difficult to communicate in solving problems when asked for an example of a real problem. Learners also cannot decide the right solution to solve a problem. This is because students still get learning that involves abstract thinking skills that do not maximize the role of learning media in the learning process. The role of learning media is crucial for the learning process. Learning media is a tool or intermediary that can connect or convey messages or information on learning materials from educators to students in the teaching and learning process. Challenges in the visualization process often arise in the study of physics due to its abstract and complex content (Akhatayeva et al., 2024; Nyirahabimana et al., 2024). Learning media can help learners improve understanding, present data, and condense information. Through digital media

and various types of technology, it can support learners in discovering and understanding knowledge. The integration of technological resources in the realm of scientific education facilitates the explanation of complex concepts, enhances the tangible nature of the learning process, streamlines the implementation of experimental procedures, and fosters the organization of educational settings according to the diverse individual characteristics of the student population (Laumann et al., 2024; Lahme et al., 2023; Putranta et al., 2019).

Based on the above background, a Systematic Literature Review on the use of media in problem-based learning models in physics learning was conducted. This is important to do because, through a Systematic Literature Review, researchers can present complete and accurate facts about the benefits of media used in problem-based learning models in supporting the learning process to improve students' physics learning outcomes. So that other researchers can refer to this Systematic Literature Review as a theoretical basis for making the right media that can be used in physics learning with problem-based learning models. Therefore, this study aims to see the trend of media use in learning activities with problem-based learning models. Articles were analyzed to find out the questions above.

Systematic review questions:

a. What is the research trend of Problem-Based learning in 2014-2024?
b. What methods were used in Problem-Based learning research in 2014-2024?
c. What are the physics materials studied in Problem-Based learning research in 2014-2024?
d. How are the variables associated with Problem-Based learning research in 2014-2024?
e. What types of media are used in Problem-Based Learning (PBL)?
f. What are the research results conducted on problem-based learning from 2014 to 2024?

The implementation of a Systematic Literature Review (SLR) in this context serves to comprehensively identify and categorize the various types of instructional media used in the Problem-Based Learning (PBL) model. Through a systematic analysis of relevant scholarly articles, this review presents a structured overview of the tools and technologies that have been effectively applied in PBL-based instruction. The information obtained from this review can assist educators and researchers in understanding current trends in media use, selecting appropriate media, and enhancing the quality of PBL implementation. Furthermore, the findings may serve as a reference for future research and innovation in the design of PBL-based learning environments.

METHOD

The PRISMA statement was used to make the systematic literature review more effective (Page et al., 2021; Liberati et al., 2009; Moher et al., 2009). It consists of four stages: identification, screening, eligibility, and inclusion, which were adopted to conduct the review of the collected articles. The diagram is presented in Figure 1.

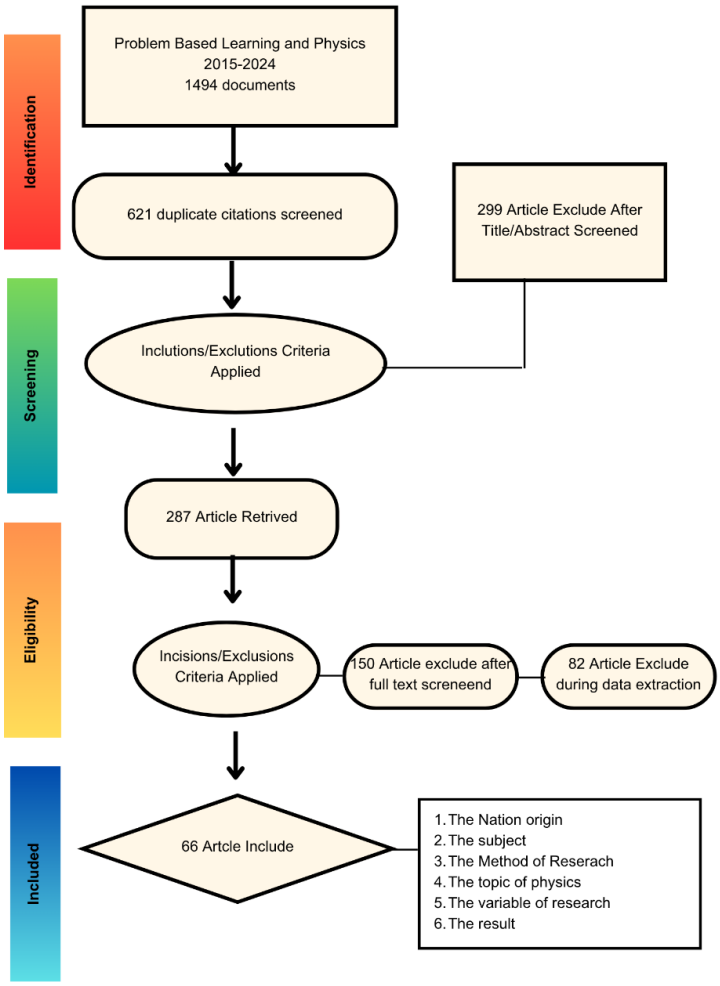

Figure 1. Flowchart of literature review

1. Eligibility Requirements

Problem-based learning was the subject of all the initial studies. Studies were identified by looking at relevant publications from the last five years, from 2020-2024. Data was found using Publish or Perish, ERIC, Scopus, and SINTA journals. Articles were reviewed to determine the appropriateness of the chosen subject. All papers related to social science were written in English and indicated that the research was a scientific study. The journals where the articles were published were reviewed, for example: American Journal of Educational Research, Eurasian journal of physics and chemistry education, EURASIA Journal of Mathematics Science and Technology Education., Journal of Baltic Science Education, Thinking Skills and Creativity, Advances in Natural and Applied Sciences, International Journal of Electrical Engineering Education, Computers & education, Journal of Baltic Science Education, Interdisciplinary Journal of Problem-Based Learning, Physical Review Physics Education Research, Asia-Pacific Forum on Science Learning and Teaching, European Journal of Educational Research, Journal for the Education of Gifted Young Scientists, Jurnal Pendidikan IPA Indonesia, International Journal of Evaluation and Research in Education (IJERE), Solid State Technology, F1000Research, Education sciences, International Journal of Innovation in Science and Mathematics Education, International Journal of Interactive Mobile Technologies (IJIM), International Journal of Information and Education Technology, Physics Educations, Qubahan Academic Journal, Jurnal Ilmiah Pendidikan Fisika Al-BiRuNi, Jurnal Pendidikan Fisika Indonesia, International Journal

of Pedagogy and Teacher Education (IJPTE), IJIS Edu : Indonesian Journal Integration Science Education, Jurnal Penelitian Pendidikan IPA, Jurnal Ilmu Pendidikan Fisika, and Momentum: Physics Education Journal.

2. Search Technique

The search process used keywords such as "problem-based learning" and "problem-based learning physics." This method used the publish or perish platform, Scopus, and Google Scholar. Articles were then selected with the limitation that this problem-based learning Model research uses media in its learning or the development of learning media based on the problem-based learning model. In addition, the criteria for the articles analyzed are presented in Table 1.

Table 1. Criteria for articles to be analyzed

Criteria Analyzed	Exclusion Criteria
Articles relevant to the research topic, including: a. Learning with the Problem-Based Learning (PBL) model b. PBL learning physics material c. Articles indexed in Scopus or Sinta 1 or Sinta 2 d. Published 2015-2024 e. Using international languages	a. Literature studies other than journals, such as papers, theses, and books b. Journal articles not related to the topic c. Articles published outside the 2015-2024 timeframe d. Articles not published in an international language

This literature review's limitation is access to international journal platforms, which cannot be obtained for free. The authors of this literature review were from Indonesia, so it was easier to find articles in Indonesia. Article searches are only from International and Indonesian platforms.

3. Process for Study Selection and Data Collection

The first step in selecting studies was browsing the title, abstract, and conclusion to determine whether the article was the result of research conducted on the subject or course of physics. After that, the full text of the articles was viewed to assess their eligibility. After the review was carried out according to the criteria of the article, data analysis was carried out. Data was collected, analyzed, and processed using Excel. Data visualization uses Tableau, Excel, and Canva.

RESULT AND DISCUSSION

The collected articles were reviewed and analyzed. The results of the data review included: 1) Country or place of research; 2) Trends in the year of publication of the article; 3) Keywords; 4) Research methods; 5) Physics material taught; 6) Research results; 7) related variables; and 8) learning media used.

1. Trends Research

a. Country

Based on the country of origin, the findings from the analysis of articles that were obtained within the period 2015-2024 were found in 14 countries. The results of the analysis show that the 14 countries are France, Turkey, Ethiopia, Indonesia, Malaysia, the United States, Spain, South Korea, Uganda, the Netherlands, Lithuania, Brazil, México, and Nigeria (Affandy et al., 2024; Sunarti et al., 2024; Aristaria et al., 2024; Marcinauskas et al., 2024; Sedayu et al., 2024; Gumisirizah et al., 2024; Distrik et al., 2024; Wijaya et al, 2024; Nenggala et al., 2024; Rizal et al., 2024; Salazar et al., 2023; Almeida & Chiaro, 2023; Lee et al., 2023; Sulaiman et al., 2023; Setiati& Jumadi, 2023; Fathurohman et al., 2023; Imaniah et al., 2023; Masrifah & Amiroh, 2023; Nilyani & Ratnawulan, 2023; Oksaviona et al., 2023; Oktariya et al., 2023; Otu & Budiningsih, 2023; Suryanti & Festiyed, 2023; Arzak & Prahani, 2023; Jamaludin et al., 2022; Melawati et al., 2022; Nurmasyitah et al., 2022; Dalila et al., 2022; Damayanti & Yohandri, 2022; Kanyesigye et al., 2022; Fuadi et al., 2022; Andi et al., 2021; Putri et al., 2021; Rahmadita et al., 2021; Rahmawati et al., 2021; Yanto et al., 2021; Batlolona et al., 2020; Rahmawati et al., 2020; Pawlak et al., 2020; Marnita et al., 2020; Rosales et al., 2020; Batlolona & Souisa, 2020; Akhdinirwanto et al., 2020; Yuberti et al., 2019;

Kawuri et al., 2019; Parno et al., 2019; Fidan & Tuncel, 2019; Putranta & Wilujeng, 2019; Alemany et al., 2019; Gunawan et al., 2019; Liu et al., 2019; Heng, 2018; Ismail et al., 2018; Jatmiko et al., 2018; Wartono et al., 2018: Diani et al., 2018; Orji & Ogbuanya, 2018; Sulasih et al., 2018; Mundilarto & Ismoyo, 2017; Shishigu et al., 2017; Siew & Mapeala, 2017; Ardianto & Rubini, 2016; Argaw et al., 2016; Haji et al., 2015; Ageorges et al., 2014; Tasoğlu & Bakaç, 2014). Indonesia is the country with the highest number of research studies related to problem-based learning, with 46 articles. Meanwhile, other countries counted about one to three articles per country. The trend of countries conducting problem-based learning research is presented in Figure 2.

Figure 2 shows the total number of articles based on the country where the research was conducted. The number of articles based on the country where the research was conducted is as follows: Indonesia (N=47), Malaysia (N=2), Turkey (N=2), Ethiopia (N=2), Korea (N=2), Uganda (N=2), United States (N=3), France (N=1), Spain (N=1), Netherlands (N=1), Lithuania (N=1), Brazil (N=1), Mexico (N=1), and Nigeria (N=1). Indonesia contributed the highest number of articles among all countries represented.

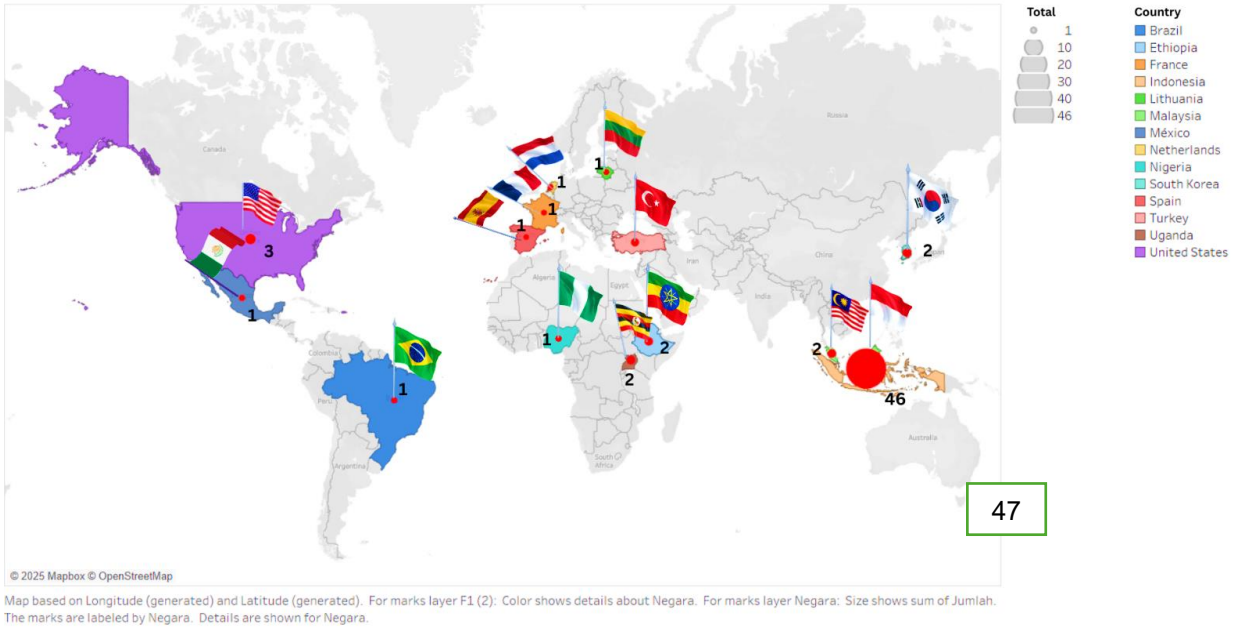

Figure 2. The trend of countries where Problem-Based Learning is being researched

Then, further analysis was carried out for research conducted in Indonesia, totalling 47 articles.(Wijaya et al., 2024; Affandy et al., 2024; Razi, 2024; Sunarti et al., 2024; Nenggala et al., 2024; Rizal et al., 2024; Sedayu et al., 2024; Aristaria et al., 2024; Distrik et al., 2024; Anggraini et al., 2023; Arzak & Prahani, 2023; Imaniah et al., 2023; Fathurohman et al., 2023; Masrifah & Amiroh, 2023; Oksaviona et al., 2023; Oktariya et al., 2023; Otu & Budiningsih, 2023; Nilyani & Ratnawulan, 2023; Setiati & Jumadi, 2023; Suryanti & Festiyed, 2023; Dalila et al., 2022; Damayanti & Yohandri, 2022; Jamaludin et al., 2022; Nurmasyitah et al., 2022; Melawati et al., 2022; Yanto et al., 2021; Andi et al., 2021; Putri et al., 2021; Rahmadita et al., 2021; Rahmawati et al., 2021; Akhdinirwanto et al., 2020; Batlolona et al., 2020; Rahmawati et al., 2020; Marnita et al., 2020; Kawuri et al., 2019; Parno et al., 2019; Yuberti et al., 2019; Gunawan et al., 2019; Sulasih et al., 2018; Wartono et al., 2018; Diani et al., 2018; Jatmiko et al., 2018; Ismail et al., 2018; Mundilarto & Ismoyo, 2017; Ardianto & Rubini, 2016; Haji et al., 2015). The province with the most research was conducted in East Java Province, totalling nine studies; the second place is Lampung Province, totalling six studies, and West Java and Central Java, with five studies, and other provinces, totalling one to four studies. The data is

presented in the visualization of problem-based learning research trends in Indonesia in Figure 3.

Figure 3 presents the number of research articles conducted in each region across Indonesia. The number of articles based on research location is as follows: East Java (N=9), Lampung (N=6), Central Java (N=5), West Java (N=5), Yogyakarta (N=3), Aceh (N=4), West Sumatra (N=4), Maluku (N=2), North Maluku (N=2), West Nusa Tenggara (N=2), East Nusa Tenggara (N=2), South Sumatra (N=1), Riau (N=1), and Jambi (N=1). East Java is the most studied region in problem-based learning research.

The analysis of Indonesian-based articles reveals that no studies on problem-based learning were conducted in Sulawesi, Kalimantan, or Papua. This absence is likely due to the scope of the review being limited to articles indexed in Scopus and SINTA 1 or 2, which did not include research from these regions.

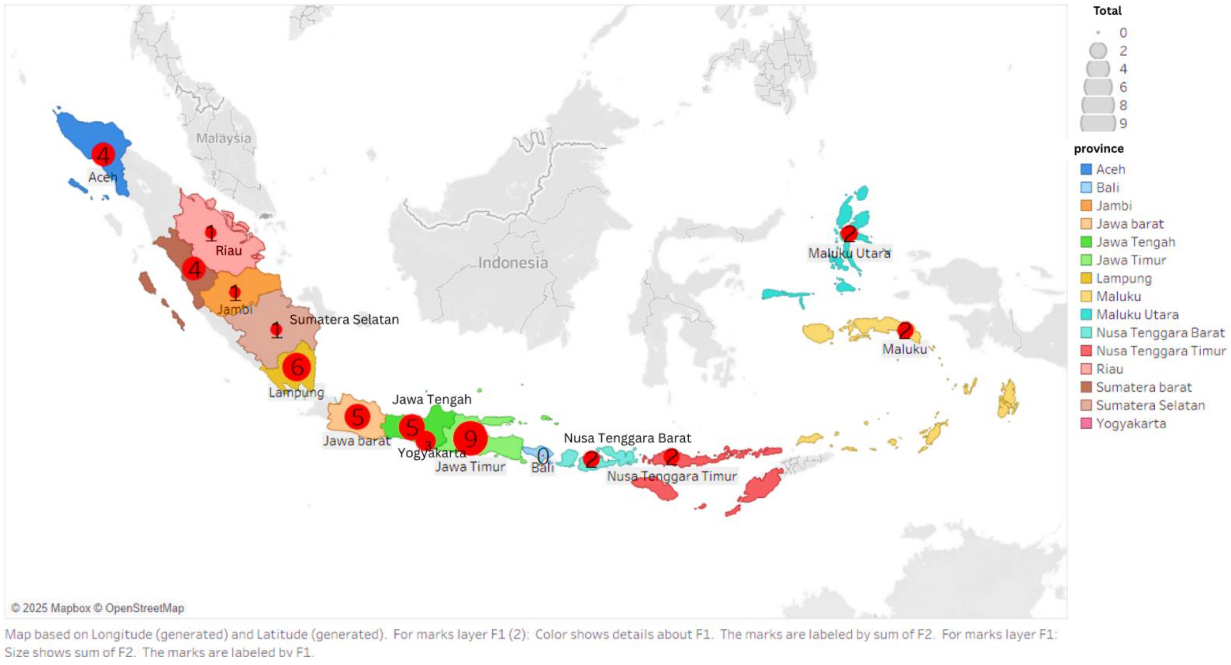

Figure 3. Research trend of Problem-Based Learning in Indonesia

b. Year

The results of the analysis of articles obtained on the topic of problem-based learning in physics were mostly carried out in 2023. As many as 15 articles were published in that year.

Research with the theme of problem-based learning in physics increased from 2016 to 2017 and began to decline again in 2021. However, it experienced a surge in research, especially in Indonesia, in 2023. Figure 4 displays the publication year trend of the articles.

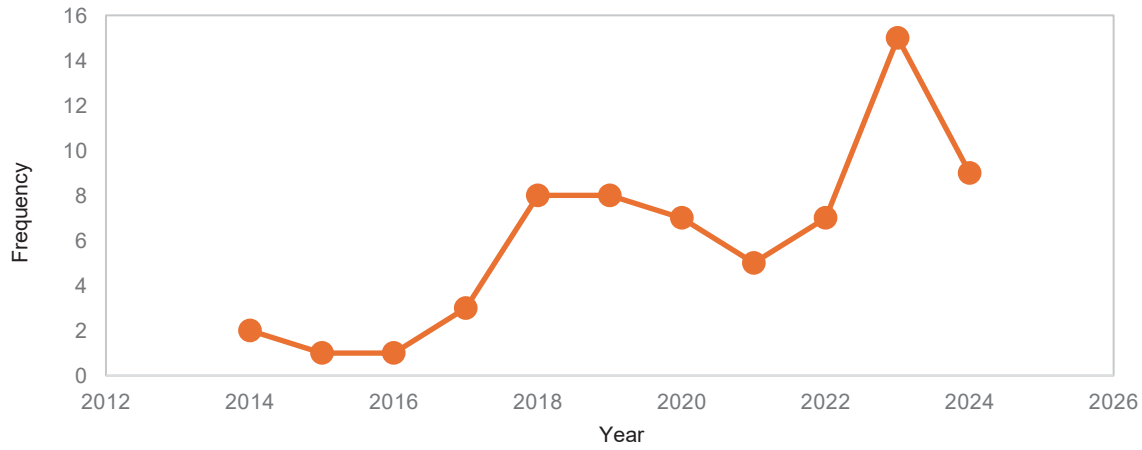

Figure 4. Trends in the year of publication of the research articles analyzed

c. Journal

The articles obtained mainly were published in Sinta 2-indexed journals; Sinta itself stands for Science and Technology Index. Sinta is a scientific portal or online page managed by the Ministry of Education and Culture, and Research that provides a list of accredited national journals. In addition, the journals analyzed were indexed by Scopus, and the journal publishers were international journals. The results of the analysis show that the largest number of journals are published on the platform “Jurnal Penelitian Pendidikan IPA” (N = 16), “Jurnal Pendidikan Indonesia” (5), and “Journal of Baltic Science Education” (4).

d. Keywords

The results of the review of keywords used in problem-based learning research in physics learning using Vos viewer, with data taken from Publish or Perish, whose data sources are Scopus and Google Scholar are shown in Figure 5. The most relevant results are “application of problem-based learning model," “effect of problem-based learning model,” "learning outcomes,” "PhET simulation,” and "Student understanding. "Physics learning,” "critical thinking,” and “physics module.”

In addition, problem-based learning is the process of students solving physics problems taught in physics learning at both junior and senior high school levels. This scenario demonstrates the potential of modifying methodological and thematic frameworks through a temporal continuum, which proves advantageous in the formulation of search strategies. This underscores the critical significance of precision in search methodology, given that keywords differ across different disciplines within the natural sciences. Therefore, it is imperative to include the terms “astronomy,” "biology,” "chemistry,” "geology,” and "physics” to ensure the relevance of search results.

Finally, Figure 3c illustrates the tendency to provide thematic descriptions related to specific scientific fields. This underscores the critical significance of accuracy in the search methodology, given that keywords differ across different disciplines within the natural sciences. Therefore, it is imperative to include the terms “astronomy,” "biology,” “chemistry," “geology,” and "physics” to ensure the relevance of search results.

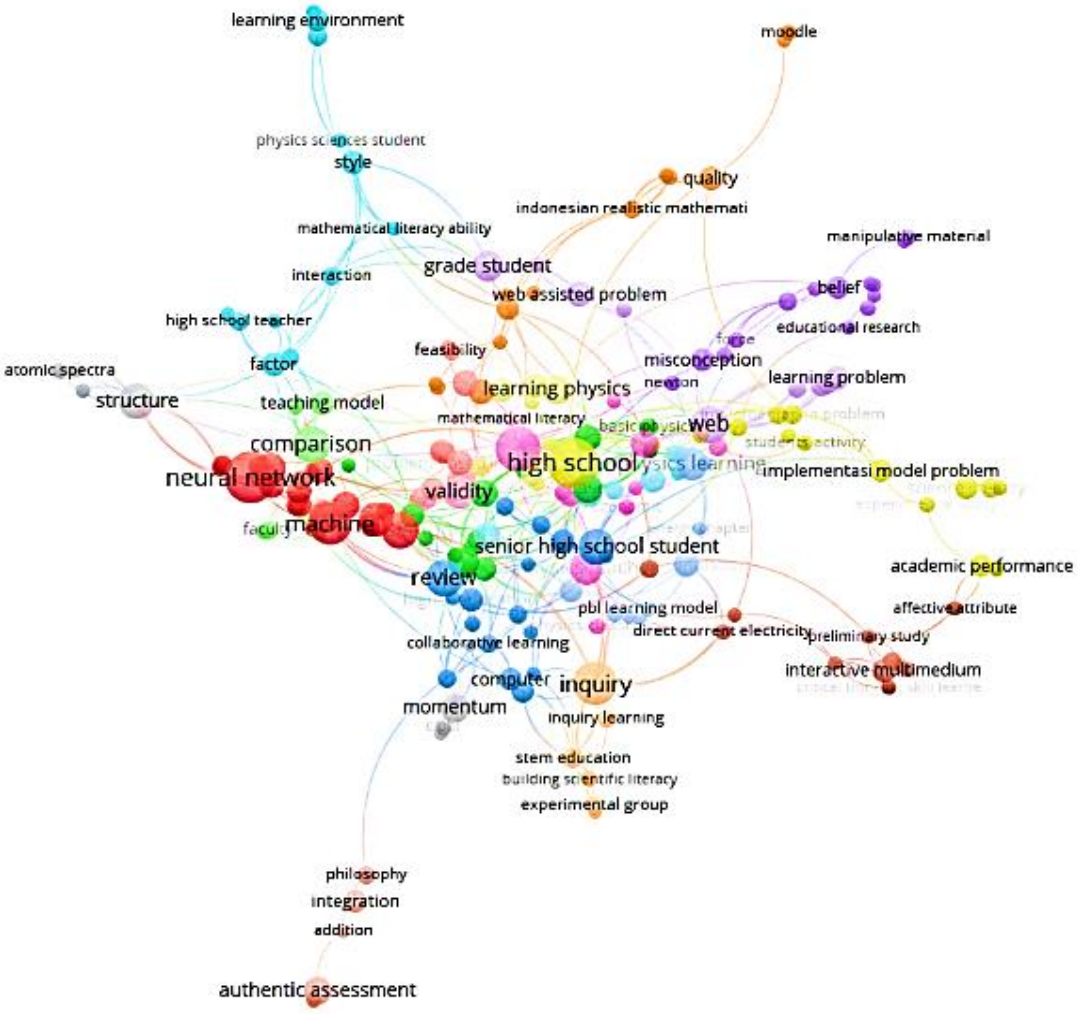

Figure 5. Keyword Problem-Based Learning physics

2. Research Methods Used

a. Type of Research

The data in Figure 6 shows the research design used by researchers conducting problem-based learning research in physics learning. Research is grouped into 5 methods: quantitative, qualitative, mixed methods, and R&D (Sugiyono 2017).

The diverse methods used in the research endeavour are illustrated in Figure 6, showing the predominance of quantitative research in the study of problem-based learning models in physics learning. Scholars use many research designs to collect data effectively when engaging in quantitative research methodologies. The analysis results show quantitative research at 57.58% (N 38), R&D at 21.21% (N = 15), Mixed methods at 10.61% (N =7), and Qualitative at 10.61% (N =7). A thorough examination of the existing literature for this article reveals that investigations of problem-based learning models in physics learning over the past 10 years were conducted largely using quantitative methods.

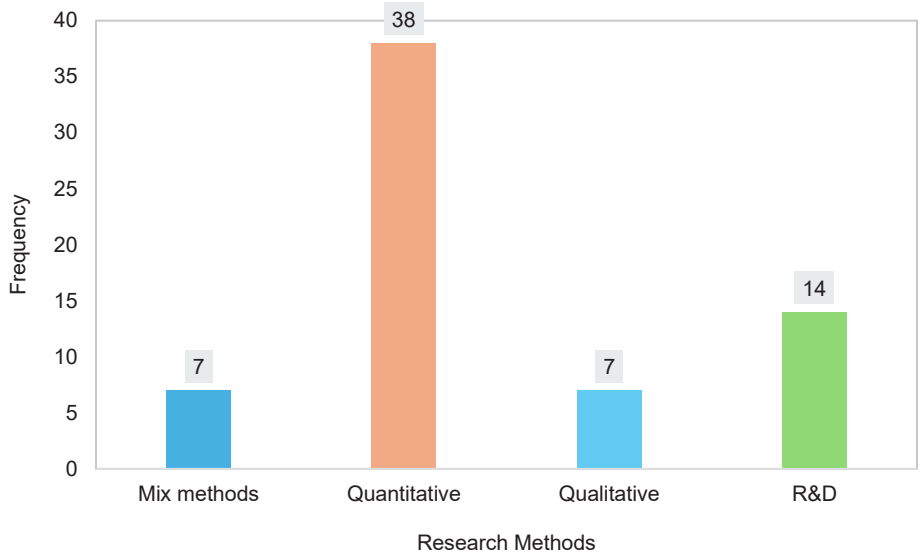

Figure 6. Type of research methods

b. Sampling Technique Used

Sampling techniques can basically be grouped into two, namely Probability Sampling and Nonprobability Sampling. Probability sampling includes simple random, proportionate stratified random, disproportionate stratified random, and area random. Non-probability sampling includes systematic, quota, incidental, purposive, saturated, and snowball sampling. (Sugiyono, 2017). The sampling technique group is presented in Table 2.

Table 2. Sampling technique

Non-Probability Sampling	Probability Sampling
1. Convenience sampling	1. Simple random sampling
2. Judgmental sampling (purposive sampling)	2. Stratified sampling
3. Quota sampling	3. Systematic sampling
4. Snowball sampling	4. Cluster sampling
	5. Proportional stratified random sampling

The data analysis results related to the sampling technique used in determining the sample to be studied in the article are presented in Figure 9. The research conducted in the analyzed articles mostly used “purposive sampling” as most of the samples were less than 100. The results of the journal analysis indicate that the most frequently used sampling technique is purposive sampling (N = 41) (Wijaya et al., 2024; Marcinauskas et al., 2024; Rizal et al., 2024; Nenggala et al., 2024; Gumisirizah et al., 2024; Lee et al., 2023; Sulaiman et al., 2023; Fathurohman et al., 2023; Almeida & Chiaro, 2023; Oksaviona et al., 2023; Setiati & Jumadi, 2023; Suryanti & Festiyed, 2023; Masrifah & Amiroh, 2023; Arzak & Prahani, 2023; Imaniah et al., 2023; Otu & Budiningsih, 2023; Nilyani & Ratnawulan, 2023; Oktariya et al., 2023; Damayanti & Yohandri 2022; Nurmasyitah et al., 2022; Fuadi et al., 2022; Dalila et al., 2022; Putri et al., 2021; Yanto et al., 2021; Rahmadita et al., 2021; Andi et al., 2021; Rahmawati et al., 2020; Rosales et al., 2020; Pawlak et al., 2020; Parno et al., 2019; Gunawan et al., 2019; Putranta & Wilujeng, 2019; Kawuri et al., 2019; Shishigu et al., 2018; Ismail et al., 2018; Heng, 2018; Mundilarto & Ismoyo, 2017; Ardianto & Rubini, 2016; Haji et al., 2015; Tasoğlu & Bakaç, 2014). One of the reasons for this is the use of technology-based learning media, which requires each student to bring an electronic device such as a mobile phone or laptop during the

learning process (Wijaya et al., 2024; Rizal et al., 2024; Aristaria et al., 2024; Arzak& Prahani, 2023; Damayanti & Yohandri, 2022; Fathurohman et al., 2023; Setiati & Jumadi 2023; Imaniah et al., 2023; Masrifah & Amiroh, 2023; Oksaviona, et al., 2023; Oktariya et al., 2023; Fuadi et al., 2022; Putri et al., 2021; Rahmadita et al., 2021; Rahmawati et al., 2021; Putranta & Wilujeng, 2019; Ismail et al., 2018). Figure 7 shows the distribution of sampling techniques from the analyzed problem-based learning articles.

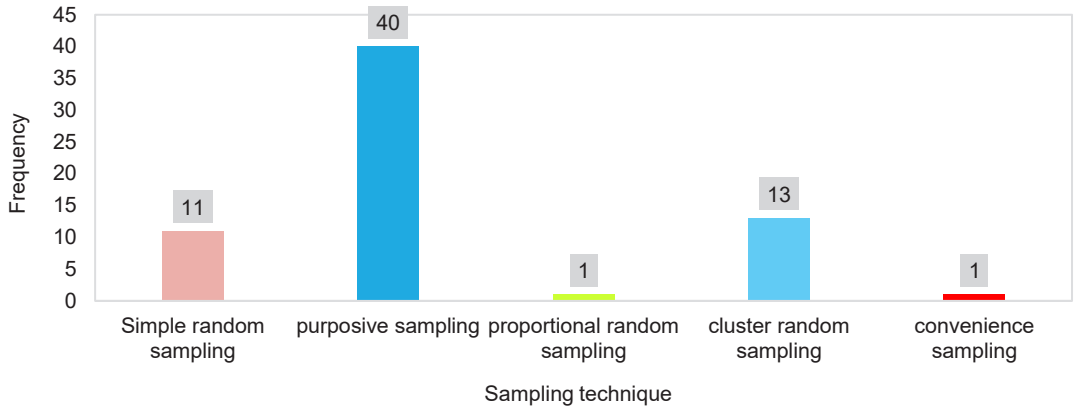

Figure 7. Sampling technique of the analyzed Problem-Based Learning articles

The results of the review and analysis found articles that used proportional random sampling techniques (Jatmiko et al., 2018) and convenience (Salazar et al., 2023). The sampling technique used in the research conducted in the article does not directly mention the sampling process. It is just that by screening the article in the section that explains the sampling process, these articles can be grouped using sampling techniques adjusted to the type of sampling technique.

3. Physics Materials

The physics materials analyzed from the articles that have been reviewed are grouped into six parts, namely groups of materials in physics including mechanics, oscillations and waves, thermodynamics, electricity and magnetism, Optics, and Modern Physics (Tipler, 2001) And the results of the article analysis indicate that some articles discuss topics of Earth physics and astrophysics in their learning implementation. So, based on the analysis results, the physics material studied is divided into seven categories: mechanics; oscillations and waves; thermodynamics; electricity and magnetism; Optics; Modern Physics; Earth physics and astrophysics.

The results of the analysis show that research on problem-based learning is mostly carried out in research with groups of mechanical material (N = 21) and Others (N = 18). The other meaning of this grouping is research that combines seven sub-materials in physics and research on the development of modules or learning media in which more than one subject or physics material is discussed. Figure 8 shows the distribution of physics content discussed in the articles.

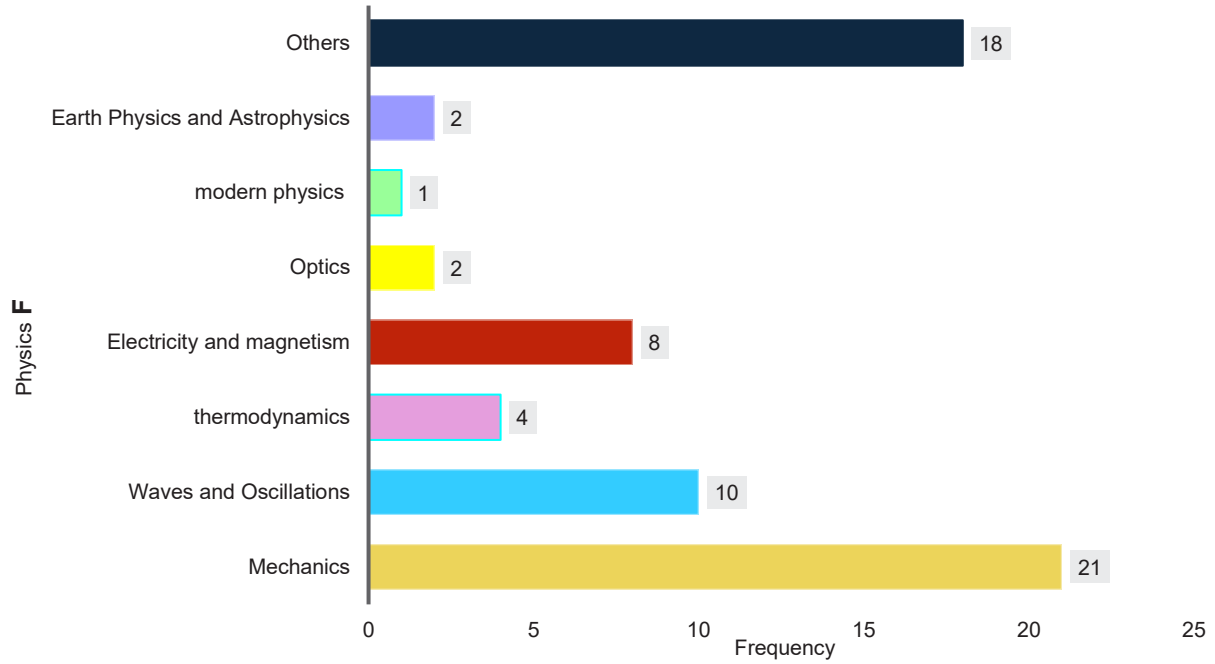

Figure 8. The distribution of physics topics studied in the articles

a. Research Results

The results of the research conducted chiefly show that the problem-based learning model or approach can improve student learning outcomes, improve critical thinking skills, student concept understanding, science literacy skills, student learning outcomes, creative thinking skills, mental models, problem solving, self-learning, argumentation skills, science process skills, team work, multi representational abilities, verbal representations, cognitive outcomes, digital literacy skills, computational physics problems skill, Students' beliefs about physics, HOTS, creative thinking style, Cognitive results and physics learning, abilities in terms of mathematical and numeracy skills (Affandy et al., 2024; Sunarti et al., 2024; Aristaria et al., 2024; Marcinauskas et al., 2024; Sedayu et al., 2024; Gumisirizah et al., 2024; Distrik et al., 2024; Wijaya et al., 2024; Nenggala et al., 2024; Rizal et al., 2024; Salazar et al., 2023; Almeida & Chiaro, 2023; Lee et al., 2023; Sulaiman et al., 2023; Setiati & Jumadi, 2023; Fathurohman et al., 2023; Imaniah et al., 2023; Masrifah & Amiroh, 2023; Oktariya et al., 2023; Otu & Budiningsih 2023; Suryanti & Festiyed, 2023; Arzak & Prahani 2023; Jamaludin et al., 2022; Melawati et al., 2022; Dalila et al., 2022; Kanyesigye et al., 2022; Fuadi et al., 2022; Andi et al., 2021; Putri et al., 2021; Rahmadita et al., 2021; Rahmawati et al., 2021; Yanto et al., 2021; Batlolona et al., 2020; Rahmawati et al., 2020; Marnita et al., 2020; Rosales et al., 2020; Batlolona & Souisa, 2020; Akhdinirwanto et al., 2020; Pawlak et al., 2020; Yuberti et al., 2019; Kawuri et al., 2019; Parno et al., 2019; Fidan & Tuncel, 2019; Putranta & Wilujeng, 2019; Alemany et al., 2019; Gunawan et al., 2019; Liu et al., 2019; Heng, 2018; Ismail et al., 2018; Jatmiko et al., 2018; Wartono et al., 2018; Orji & Ogbuanya, 2018; Sulasih et al., 2018; Mundilarto & Ismoyo, 2017; Shishigu et al., 2017; Siew & Mapeala, 2017; Ardianto & Rubini, 2016; Argaw et al., 2016; Haji et al., 2015; Ageorges et al., 2014; Tasoğlu & Bakaç, 2014).

In addition, problem-based learning is used as an approach in the development of media as the focus of the research, including the development of learning media such as e-modules, e-books, Mobile Learning, and websites (Aristaria et al., 2024; Wijaya et al., 2024; Fathurohman et al., 2023; Nilyani & Ratnawulan, 2023; Oktariya et al., 2023; Setiati & Jumadi, 2023; Oksaviona et al., 2023; Nurmasyitah et al., 2022; Fuadi et al., 2022; Diani et al., 2018).

The results of the analysis show that problem-based learning as a learning model can improve the dependent variable being studied.

However, some studies show that the results of learning using PBL are not effective in learning outcomes, but only improve students' attitudes in learning(Fidan & Tuncel, 2019). The results showed that the Problem-Based Learning (PBL) method did not enhance knowledge acquisition in mechanics compared to traditional teaching. However, PBL has a greater influence from a qualitative point of view, especially in terms of learners' attitudes towards learning.

Although quantitative results did not show that PBL was more efficient than traditional teaching, the primary influence was seen in qualitative aspects (Ageorges et al., 2014) and the results of a comparison with the OR-IPA learning model showed that learning with the OR-IPA model was more effective in improving students' critical thinking skills (Jatmiko et al., 2018). However, other studies conducted in the same year or the following year show that learning using the problem-based learning model is effective in improving the dependent variable (Affandy et al., 2024; Sedayu et al., 2024; Gumisirizah et al., 2024; Distrik et al., 2024; Sunarti et al., 2024; Marcinauskas et al., 2024; Nenggala et al., 2024; Rizal et al. 2024; Salazar et al., 2023; Almeida & Chiaro, 2023; Sulaiman et al., 2023; Lee et al., 2023; Kanyesigye et al., 2022; Rosales et al., 2020; Akhdinirwanto et al., 2020; Batlolona et al., 2020; Marnita et al., 2020; Pawlak et al., 2020; Gunawan et al., 2019; Yuberti et al., 2019; Putranta & Wilujeng, 2019; Liu et al., 2019; Alemany et al., 2019; Fidan & Tuncel, 2019; Ismail et al., 2018; Heng, 2018; Shishigu et al., 2017; Mundilarto & Ismoyo, 2017; Siew & Mapeala, 2017; Tasoğlu & Bakaç, 2014).

b. Related Variables

This problem-based learning research is associated with several other topics as variables. The dependent variable makes problem-based learning a learning model and an approach to making technology-based media. In addition, the research also conducted compared the problem-based learning model with other learning models such as traditional learning, guided discovery, direct instruction, and reciprocal learning, OR-IPA model (Sedayu et al., 2024; Gumisirizah et al., 2024; Marcinauskas et al., 2024; Jatmiko et al., 2018; Sulasih et al., 2018; Siew & Mapeala, 2017; Ardianto & Rubini, 2016). In addition, this research also collaborated with the STEM approach, Differentiation, Scaffolding, Argumentation, Mind Mapping, blended learning, and Collaborative (Sulaiman et al., 2023; Salazar et al., 2023; Almeida & Chiaro, 2023; Dalila et al., 2022; Rosales et al., 2020; Akhdinirwanto et al., 2020).

In media development research, problem-based learning is used as an approach to develop learning media such as worksheets, E-modules, E-handouts, Websites, and Augmented reality development. Problem-based learning research is also carried out by integrating PhET media into the learning process (Imaniah et al., 2023; Rahmadita et al., 2021; Putranta & Wilujeng, 2019). Figure 9 shows the relationship between problem-based learning and other variables. The broken line on the dependent variable shows that the research conducted uses two dependent variables. The dependent variable that has been studied in many studies is critical thinking (Otu & Budiningsih, 2023; Salazar et al., 2023; Fuadi et al., 2022; Rahmawati et al., 2021; Rahmadita et al., 2021; Marnita et al., 2020; Parno et al., 2019; Putranta & Wilujeng, 2019; Gunawan et al., 2019; Ismail et al., 2018; Jatmiko et al., 2018; Mundilarto & Ismoyo, 2017).

c. Learning Media Used in Problem-Based Learning Research

The results of the analysis show that the use of media in problem-based learning research aims to create media integrated with the PBL approach (Aristaria et al., 2024; Wijaya et al., 2024; Affandy et al., 2024; Sunarti et al., 2024; Nenggala et al., 2024; Rizal et al., 2024; Fathurohman et al., 2023; Nilyani & Ratnawulan, 2023; Oktariya et al., 2023; Sulaiman et al., 2023; Fathurohman et al., 2023; Setiati & Jumadi, 2023; Oksaviona et al., 2023; Suryanti & Festiyed, 2023; Masrifah & Amiroh, 2023; Melawati et al., 2022; Nurmasyitah et al., 2022; Fuadi et al., 2022; Rosales et al., 2020; Rahmawati et al., 2021; Rahmawati et al., 2020; Gunawan et al., 2019; Putranta & Wilujeng, 2019; Liu et al., 2019; Ismail et al., 2018; Diani et al., 2018; Ardianto & Rubini, 2016).

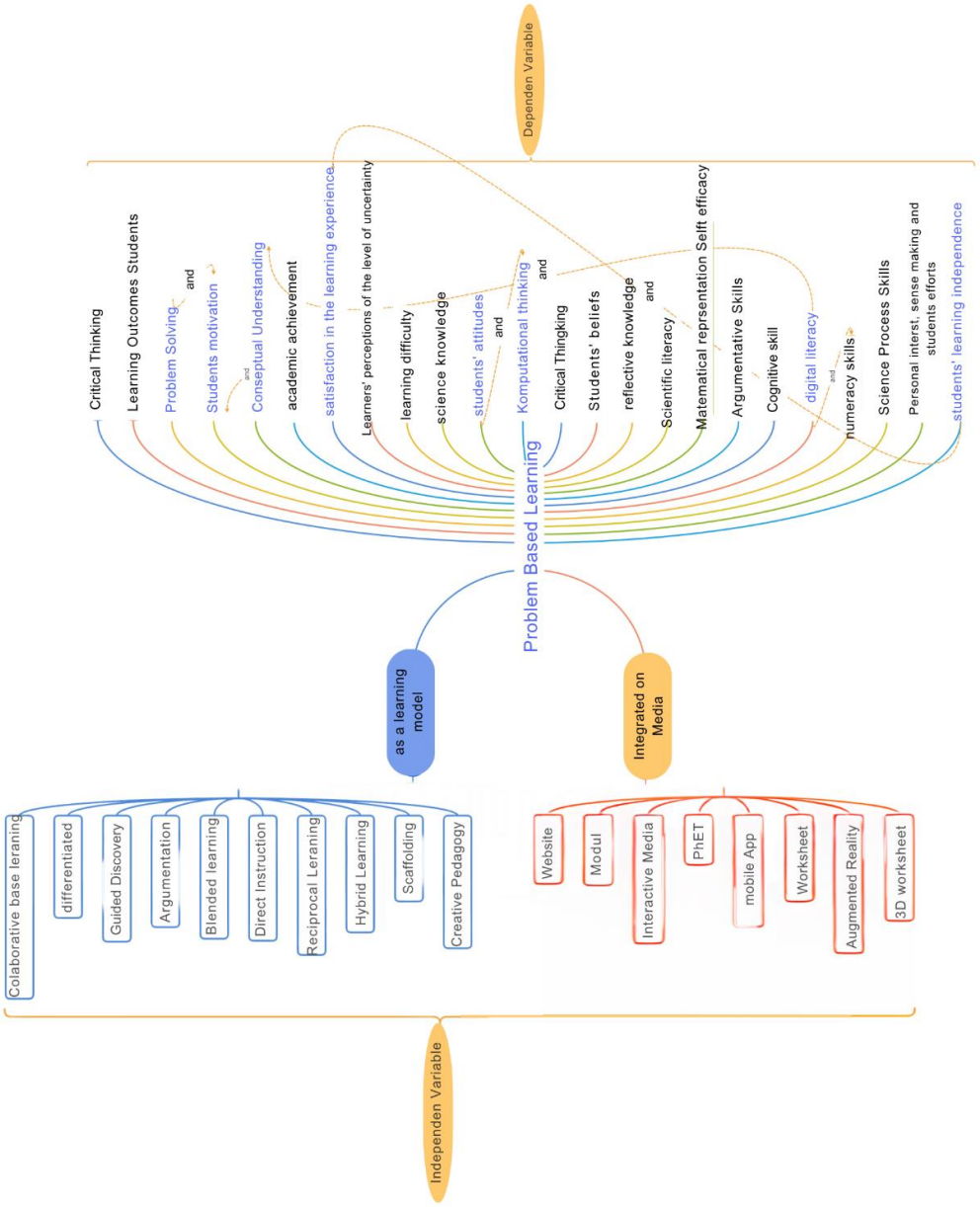

Figure 9. The scope of the research related to Problem-Based Learning as a variable

In addition, there are also those who use media as part of the learning process, which is a study of learning models that use media such as worksheets, videos, and interactive multimedia as learning media. Learning media is one of the things that can be important to be involved in learning physics, because media can be used as a tool to visualise physics material that is abstract and cannot be seen with the naked eye. The use of media provides a positive effect on physics learning (Rizal et al., 2024; Wijaya et al., 2024; Nenggala et al., 2024; Aristaria et al., 2024; Sunarti et al., 2024; Distrik et al., 2024; Setiati & Jumadi, 2023; Fathurohman et al., 2023; Suryanti & Festiyed, 2023; Oksaviona et al., 2023; Nilyani & Ratnawulan, 2023; Oktariya et al., 2023; Melawati et al., 2022; Damayanti & Yohandri, 2022; Nurmasyitah,et al., 2022; Rahmawati et al., 2021; Rahmawati et al., 2020; Fidan & Tuncel, 2019; Liu et al., 2019; Putranta et al., 2019; Gunawan, 2019; Diani et al., 2018; Ismail et al., 2018). Figure 10 illustrates the types of media used in the articles analyzed.

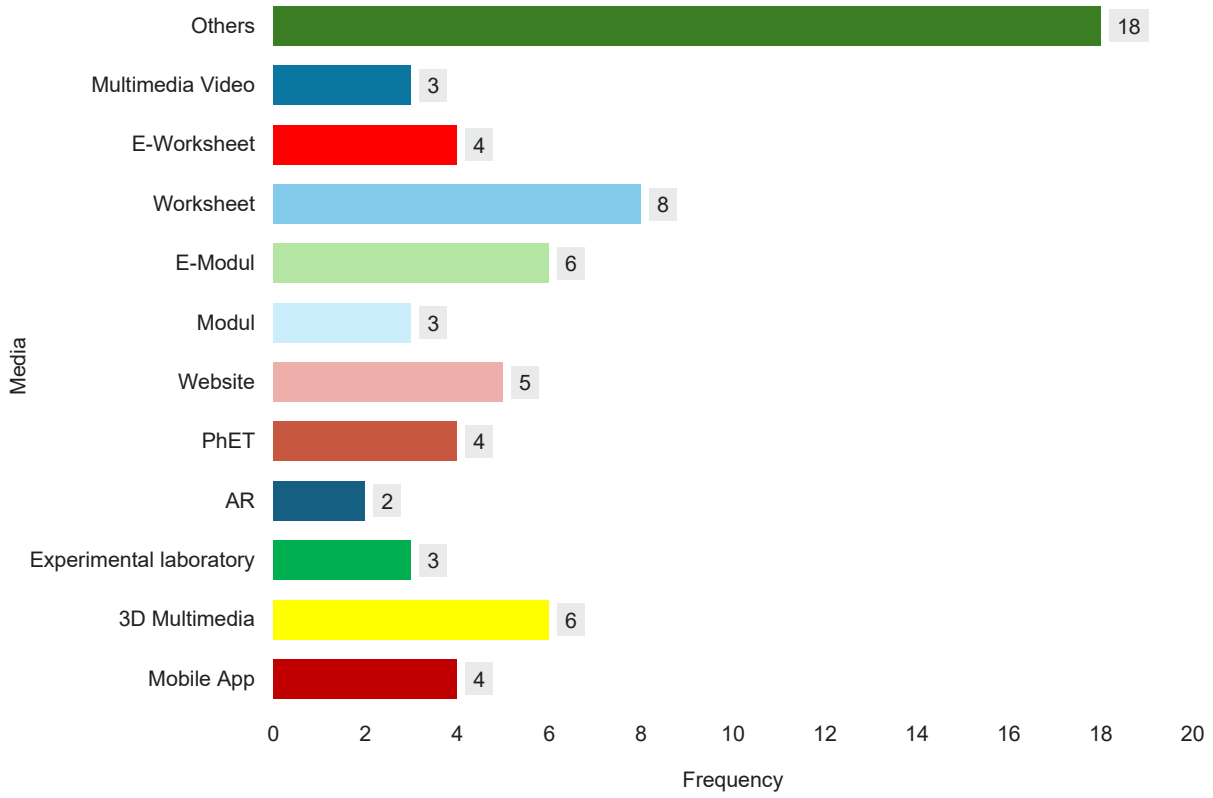

Figure 10. Media used in Problem-Based Learning research

CONCLUSION

Problem-based learning research conducted over a decade from 2014-2024 shows that the research trend from the results of the analysis of articles that have been collected, with the limitations of the difficulty of reaching international articles and journals, shows that research is mostly carried out in Indonesia, with the trend of research years often carried out in 2023. The most researched physics material is physics material related to mechanical physics sub-materials. The variables used in problem-based learning research are mostly associated with critical thinking skills as the dependent variable. In addition, problem-based learning is used as a model and an approach integrated with learning media. Most of the research methods used are quantitative methods. The results showed that problem-based learning research largely improved the dependent variable. The media that is often used in research is video multimedia, which is used as a tool in the learning process. Therefore, there is still a need for research related to the media that will be used for this problem-based learning research. This is because the research results show a significant level of effectiveness from the use of media in learning, especially by integrating problem-based learning into learning media. This SLR offers valuable insights into research patterns and gaps, serving as a reference for future studies to optimise the implementation of problem-based learning through effective media integration.

REFERENCES

Affandy, H., Sunarno,W., Suryana, R., & Harjana. (2024). Integrating Creative Pedagogy into Problem-Based Learning: The Effects on Higher Order Thinking Skills in Science Education. *Thinking Skills and Creativity* 53:101575. doi:10.1016/j.tsc.2024.101575.

Ageorges, P., Bacila,A., Poutot, G., & Bernard, B. (2014). Some Lessons from a 3-Year Experiment of Problem-Based Learning in Physics in a French School of Engineering. *American Journal of*

Educational Research 2(8):564–67. doi:10.12691/education-2-8-1.

Akhatayeva, Z., Sagindykov, K., Mukushev, B., Kurmangaliyeva, N., & Karipzhanova, A. (2024). Visual Basic and MathCAD Used for Visualization and Modeling STEM Education. *Education and Information Technologies* 29(17):23011–26. doi:10.1007/s10639-024-12776-y.

Akhdinirwanto, R. W., R. Agustini, & Jatmiko, B. (2020). Problem-Based Learning with Argumentation as a Hypothetical Model to Increase the Critical Thinking Skills for Junior High School Students. *Jurnal Pendidikan IPA Indonesia* 9(3):340–50. doi:10.15294/jpii.v9i3.19282.

Andi, H. J., Umamah, C., & Suana, W. (2021). The Effectivity of Problem Based Learning with Scaffolding on Creative Thinking Ability of Senior High School Students in Terms of Gender. *JIPF (Jurnal Ilmu Pendidikan Fisika)* 6(2):122. doi:10.26737/jipf.v6i2.1768.

Anggraini, D., Yustina, Y., Daryanes, F., & Natalina, M. (2023). Influence of Problem-Based Learning and Blended Learning on Students' Creative Thinking Ability in Class XI SMAN Plus Riau Province Material Body Defense System. *Jurnal Penelitian Pendidikan IPA* 9(4):1916–21. doi:10.29303/jppipa.v9i4.1973.

Ardianto, D., and B. Rubini. (2016). Comparison of Students' Scientific Literacy in Integrated Science Learning through Model of Guided Discovery and Problem Based Learning. *Jurnal Pendidikan IPA Indonesia* 5(1):31–37. doi:10.15294/jpii.v5i1.5786.

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). doi:10.12973/eurasia.2017.00647a.

Aristaria, A., Wilujeng, I., & Herawati, N., I. (2024). Development of Physics Interactive Learning Media Based on Problem Based Learning Assisted by SAC Application to Improve Student Problem Solving Ability. *Jurnal Penelitian Pendidikan IPA* 10(4):1731–38. doi:10.29303/jppipa.v10i4.6082.

Arzak, K. A., & Prahani, B. K. (2023). The Physics Problem Solving Skills Profile of High School Students in Elasticity Material and the Implementation of Augmented Reality Book-Assisted PBL Model. *Momentum: Physics Education Journal* 7(1). doi:10.21067/mpej.v7i1.6704.

Batlolona, J. R., & Souisa, H. F. (2020). Problem based learning: Students' mental models on water conductivity concept. International Journal of Evaluation and Research in Education (IJERE), 9(2), 269-277. doi:10.11591/ijere.v9i2.20468

Batlolona, J. R., S. Singerin, & Diantoro, M. (2020). Influence of Problem Based Learning Model on Student Mental Models. *Jurnal Pendidikan Fisika Indonesia* 16(1):14–23. doi:10.15294/jpfi.v16i1.14253.

Almeida, Jeyvson, and Sylvia De Chiaro. (2023). "Argumentação E Aprendizagem Baseada Em Problemas: Processo De Construção De Conhecimento Crítico E Reflexivo Em Sala De Aula De Física *Investigações Em Ensino de Ciências* 28(2):462–83. doi:10.22600/1518-8795.ienci2023v28n2p462.

Dalila, A., A., Rahmah, S., Liliawati, W., & Kaniawati, I. (2022). Effect of Differentiated Learning in Problem Based Learning on Cognitive Learning Outcomes of High School Students. *Jurnal Penelitian Pendidikan IPA* 8(4):2116–22. doi:10.29303/jppipa.v8i4.1839.

Damayanti, Retno, I., & Yohandri. (2022). E-Book Development Effectiveness Problem Based Learning with Quizing in Physics Learning." *Jurnal Penelitian Pendidikan IPA* 8(6):3044–49. doi:10.29303/jppipa.v8i6.2290.

Diani, R., Yuberti, & Syarlisjiswan, 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):105–16. doi:10.24042/jipfalbiruni.v7i1.2849.

Kamaliya, D. H., Tukiran, & Indana, S. (2022). Profile of Electronic and Digital Media Learning Implementation During 2018-2022. *IJORER : International Journal of Recent Educational Research* 3(3):354–63. doi:10.46245/ijorer.v3i3.213.

Distrik, I. W., C., Ertikanto, Y., S., Purwati, A., S., & Rahman, N F., A. (2024). Digital Problem-Based Worksheet with 3D Pageflip: An Effort to Address Concept Understanding Problems and Enhance Digital Literacy Skills. *Jurnal Pendidikan IPA Indonesia* 13(1):116–27. doi:10.15294/jpii.v13i1.48604.

Batlolona, J. R., Singerin, S., & Diantoro, M. (2020). Influence of Problem Based Learning Model on student creative thinking on elasticity topics a material. Jurnal Pendidikan Fisika Indonesia, 16(1), 14-23.

Fathurohman, A., Murniati, Sukemi, Susiloningsih, E., Erni, Kurdiati, L. A., & Samsuryadi. (2023). Developing Mobile Learning of Physics (MOBLEP) with Android-Based Problem-Based Learning

Approach to Improve Students' Learning Independence. *Momentum: Physics Education Journal* 7(1):125–35. doi:10.21067/mpej.v7i1.7980.

Fidan, M., & Tuncel, M. (2019). Integrating Augmented Reality into Problem Based Learning: The Effects on Learning Achievement and Attitude in Physics Education. *Computers and Education* 142. doi:10.1016/j.compedu.2019.103635.

Fuadi, H., Gunawan, & Susilawati. (2022). Feasibility of PBL (Problem Based Learning)-Based Sound Wave Electronic Student Worksheet for High School Students Using the Liveworksheet Application. *Jurnal Penelitian Pendidikan IPA* 8(4):2255–65. doi:10.29303/jppipa.v8i4.1982.

Gumisirizah, N., Muwonge, C., M., & Nzabahimana, J. (2024). Boosting Learning Achievement in Physics among Ugandan Form-2 Students: Effect of Problem-Based Learning. *Physics Education* 59(1):015006. doi:10.1088/1361-6552/acfebb.

Gumisirizah, N., Muwonge,C., M., & Nzabahimana, J. (2024). Effect of Problem-Based Learning on Students' Problem-Solving Ability to Learn Physics. *Physics Education* 59(1):015015. doi:10.1088/1361-6552/ad0577.

Gunawan, Harjono, A., Heryati, L., & Husein, S. (2019). Problem-Based Learning Approach with Supported Interactive Multimedia in Physics Course: Its Effects on Critical Thinking Disposition. *Journal for the Education of Gifted Young Scientists* 7(4):1075–89. doi:10.17478/jegys.627162.

Haji, A. G., Safriana, and Safitri, R. (2015). The Use of Problem Based Learning to Increase Students' Learning Independent and to Investigate Students' Concept Understanding on Rotational Dynamic at Students of SMA Negeri 4 Banda Aceh. *Jurnal Pendidikan IPA Indonesia* 4(1):67–72. doi:10.15294/jpii.v4i1.3503.

Heng, K., H. (2018). Investigating Learners' Perception of Uncertainty Level and Satisfaction in Learning Experience in an Authentic Problem-Based Learning Classroom." *Advances In Natural And Applied Sciences*. doi:10.22587/anas.2018.12.4.7.

Imaniah, E., Susilawati, Sutrio, & Kosim. (2023). Effect of the PhET Assisted Problem Based Learning Model on Student Learning Outcomes in Wave Material. *Jurnal Penelitian Pendidikan IPA* 9(6):4731–37. doi:10.29303/jppipa.v9i6.3836.

Ismail, Syazwani, N., Harun, J., Zakaria, & Salleh, S. M. (2018). The Effect of Mobile Problem-Based Learning Application DicScience PBL on Students' Critical Thinking. *Thinking Skills and Creativity* 28:177–95. doi:10.1016/j.tsc.2018.04.002.

Jamaludin, Wenno, I. H., Batlolona, J. R. (2022). The Effect of Problem-Based Learning and Students' Understanding of Physics Concepts On The Topic of The Doppler Effect. *JIPF (Jurnal Ilmu Pendidikan Fisika)* 7(2):192. doi:10.26737/jipf.v7i2.2720.

Jatmiko, B., Prahani, B., K., Munasir, Supardi, Z., A., I., Wicaksono, I., Erlina, N., Pandiangan,P., Althaf,R., & Zainuddin Zainuddin. (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. doi:10.33225/jbse/18.17.300.

Kanyesigye, S. T., Uwamahoro, & Kemeza, I. (2022). Effect of Problem-Based Learning on Students' Attitude towards Learning Physics: A Cohort Study. *F1000Research* 11:1240. doi:10.12688/f1000research.125085.1.

Tasoğlu, K., Aslıhan, & Bakaç,M. (2014). The Effect of Problem Based Learning Approach on Conceptual Understanding in Teaching of Magnetism Topics. *International Journal of Physics and Chemistry Education* 6(2):110–22. doi:10.51724/ijpce.v6i2.60.

Kawuri, M. Y., Tinon, R., Ishafit, & Fayanto, S. (2019). Efforts To Improve The Learning Activity And Learning Outcomes Of Physics Students With Using A Problem-Based Learning Model. *IJIS Edu : Indonesian Journal of Integrated Science Education* 1(2). doi:10.29300/ijisedu.v1i2.1957.

Lahme, S. Z., Klein, P., Lehtinen, A., Müller, A., Pirinen, P., Rončević, L., & Sušac, A. (2023). Physics lab courses under digital transformation: A trinational survey among university lab instructors about the role of new digital technologies and learning objectives. *Physical Review Physics Education Research, 19(2),* 020159. https://doi.org/10.1103/PhysRevPhysEducRes.19.020159

Laumann, D., Schlummer, P., Abazi, A., Borkamp, R., Lauströer, J., Pernice, W., Schuck, C., Schulz-Schaeffer, R., & Heusler, S. (2024). Analyzing the Effective Use of Augmented Reality Glasses in University Physics Laboratory Courses for the Example Topic of Optical Polarization. *Journal of Science Education and Technology, 33(5),* 668–685. https://doi.org/10.1007/s10956-024-10112-0

Lee, M., Cormac, Larkin, J. K., & Hoekstra, S. (2023). Impacts of Problem-Based Instruction on Students' Beliefs about Physics and Learning Physics. *Education Sciences* 13(3):321. doi:10.3390/educsci13030321.

Liberati, A., Altman,D., G., Tetzlaff, J., Mulrow, C., Gøtzsche, P., C., Ioannidis, J., P., A., Clarke, M.,

Devereaux, P., J., Kleijnen, J., & Moher, D. (2009). The PRISMA Statement for Reporting Systematic Reviews and Meta-Analyses of Studies That Evaluate Health Care Interventions: Explanation and Elaboration. *Journal of Clinical Epidemiology* 62(10):e1–34. doi:10.1016/j.jclinepi.2009.06.006.

Liu, M., Liu, S., Pan, Z., Zou, W., & Li, C. (2019). Examining Science Learning and Attitude by At-Risk Students After They Used a Multimedia-Enriched Problem-Based Learning Environment. *Interdisciplinary Journal of Problem-Based Learning* 13(1). doi:10.7771/1541-5015.1752.

Marcinauskas, L., Iljinas, A., Čyvienė, J., & Stankus, V. (2024). Problem-Based Learning versus Traditional Learning in Physics Education for Engineering Program Students. *Education Sciences* 14(2):154. doi:10.3390/educsci14020154.

Marnita, M. T., Iskandar, and Rahmi. (2020). The Effect Of Blended Learning Problem-Based Instruction Model On Students' Critical Thinking Ability In Thermodynamic Course. *Jurnal Pendidikan IPA Indonesia* 9(3):430–38. doi:10.15294/jpii.v9i3.

Masrifah & Amiroh, D. (2023). The Multi-Representational Ability Profile of Physics Students in the Interactive Multimedia Assisted Problem-Based Learning during the Covid-19 Pandemic. *Momentum: Physics Education Journal* 7(2):188–200. doi:10.21067/mpej.v7i2.7501.

Melawati, O.,Halim, E., A., Yusrizal, & Elisa. (2022). Influence of the Use of Student Worksheet Problem-Based to Increase Problem Solving Skills and Learning Outcomes. *Jurnal Penelitian Pendidikan IPA* 8(1):346–55. doi:10.29303/jppipa.v8i1.1205.

Moher, D., Liberati, A., Tetzlaff, J., & Altman, D. G. (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. *PLoS Medicine* 6(7):e1000097. doi:10.1371/journal.pmed.1000097.

Mundilarto & 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):761–79. doi:10.33225/jbse/17.16.761.

Salazar, M., Laura, D., Slisko, M., H., R., J. (2023). "Critical Thinking Development in Physics Courses by PBL in Virtual Collaboration Environments. *International Journal of Innovation in Science and Mathematics Education* 31(4). doi:10.30722/IJISME.31.04.003.

Nenggala, M., P., Pakhrur, R., Hidayati, & Sari, S., Y. (2024). Electronic Student Worksheet for Solving Problems in Physics Material Based on Problem-Based Learning. *International Journal of Information and Education Technology* 14(7):945–54. doi:10.18178/ijiet.2024.14.7.2121.

Nilyani, K, & Ratnawulan. (2023). Validity of the Physics E-Module on Alternative Energy and Global Warming for Class X Based on an Integrated Problem Based Learning Model Integrated 21st Century Learning. *Jurnal Penelitian Pendidikan IPA* 9(11):10022–27. doi:10.29303/jppipa.v9i11.5512.

Nurmasyitah, Lubis, N. A., & Derlina. (2022). "Design a Problem-Based Basic Physics E-Module Using Flip PDF Corporate Edition." *Jurnal Penelitian Pendidikan IPA* 8(4):2411–17. doi:10.29303/jppipa.v8i4.1984.

Nyirahabimana, P., Minani, E., Nduwingoma, M., and Kemeza, I. (2024). Assessing the Impact of Multimedia Application on Student Conceptual Understanding in Quantum Physics at the Rwanda College of Education. *Education and Information Technologies* 29(3):3423–44. doi:10.1007/s10639-023-11970-8.

Oktariya, P., Herlina, K., & Abdurrahman. (2023). Development of Problem-Based e-LKPDs Assisted by CANVA to Stimulate Numeracy Skill and Visual Literacy. *Jurnal Penelitian Pendidikan IPA* 9(12):12303–8. doi:10.29303/jppipa.v9i12.4683.

Orji, C. T., & Ogbuanya, T. C. (2018). Assessing the Effectiveness of Problem-Based and Lecture-Based Learning Environments on Students' Achievements in Electronic Works. *International Journal of Electrical Engineering & Education* 55(4):334–53. doi:10.1177/0020720918773983.

Otu, R.,& Budiningsih, C. (2023). Effect of the Problem-Based Learning Model on Students Critical Thinking Skills and Self-Confidence. *Jurnal Penelitian Pendidikan IPA* 9(11):9829–37. doi:10.29303/jppipa.v9i11.4435.

Page, M. J., et al. (2021). The PRISMA 2020 Statement: An Updated Guideline for Reporting Systematic Reviews. *Systematic Reviews* 10(1):89. doi:10.1186/s13643-021-01626-4.

Pawlak, A., Irving, P. W., & Caballero, M. D. (2020). Learning assistant approaches to teaching computational physics problems in a problem-based learning course. *Physical Review Physics Education Research*, 16 (010139), 1-30. DOI: 10.1103/PhysRevPhysEducRes.16.010139.

Parno, P., Asim, A., Suwasono, P., & Ali, M. (2019). The Influence of Problem Based Learning on Critical Thinking Ability for Students in Optical Instrument Topic. *Jurnal Pendidikan Fisika Indonesia* 15(1):39–45. doi:10.15294/jpfi.v15i1.19309.

Prahani, B., K., Rizki, I., A., Khoirunnisa', Citra, N., F., Alhusni, H., Z., & Wibowo, F., C. (2022). Implementation of Online Problem-Based Learning

Assisted by Digital Book with 3D Animations to Improve Student's Physics Problem-Solving Skills in Magnetic Field Subject. *Journal of Technology and Science Education* 12(2):379. doi:10.3926/jotse.1590.

Putranta, H. & Wilujeng, I. (2019). Physics Learning by PhET Simulation-Assisted Using Problem Based Learning (PBL) Model to Improve Students' Critical Thinking Skills in Work and Energy Chapters in MAN 3 Sleman. *Asia-Pacific Forum on Science Learning and Teaching*, 20(1), 1-44.

Putri, W. E., Sunarno, W., Marzuki, A. (2021). Analysis of The Students' Argumentative Skills of Senior High School in Covid-19 Pandemic Using Problem Based Learning in Static Fluid. *Jurnal Penelitian Pendidikan IPA* 7(3):335–43. doi:10.29303/jppipa.v7i3.735.

Rahmadita, N., Mubarok, H., & Prahani B., K.. (2021). Profile of Problem-Based Learning (PBL) Model Assisted by PhET to Improve Critical Thinking Skills of High School Students in Dynamic Electrical Materials. *Jurnal Penelitian Pendidikan IPA* 7(4):617–24. doi:10.29303/jppipa.v7i4.799.

Rahmasari, A., & Kuswanto, H. (2023). The Effectiveness of Problem-Based Learning Physics Pocketbook Integrating Augmented Reality with the Local Wisdom of Catapults in Improving Mathematical and Graphical Representation Abilities. *Journal of Technology and Science Education* 13(3):886. doi:10.3926/jotse.1962.

Rahmawati, D., U., Wilujeng I., Jumadi, Kuswanto, H., Sulaeman, N., F., & Astuti, D.F. (2020). Problem-Based Learning E-Handout: Improving Students' Mathematical Representation and Self-Efficacy. *Jurnal Ilmiah Pendidikan Fisika Al-Biruni* 9(1):41. doi:10.24042/jipfalbiruni.v9i1.4607.

Rahmawati, F, Sarwanto, &Budiawanti, S. (2021). Needs Analysis of Physics E-Module Based on Hybrid-PBL Model on Critical Thinking Skills Improvement. *Momentum: Physics Education Journal* 175–81. doi:10.21067/mpej.v5i2.5740.

Rizal, R., Surahman, E., Aripin, H., & Maulidah, R. (2024). Problem-Based Learning Management System (PBLMS): A Mobile Learning Application to Facilitate Creative Thinking Skills (CTS) of Prospective Physics Teachers. *International Journal of Interactive Mobile Technologies (IJIM)* 18(01):97–109. doi:10.3991/ijim.v18i01.46417.

Rosales JR, J., R., & Sulaiman, F. (2020). The Effectiveness of Integrated STEM-PBL Physics Module on Students' Beliefs about Physics and Learning Physics. *Solid State Technology*, 63 (6), 19434-19449.

Alemany, S., et al. (2019). Problem-Based Structure for a Teaching-Learning Sequence to Overcome Students' Difficulties When Learning about Atomic Spectra. *Physical Review Physics Education Research* 15(2):020138.doi:10.1103/PhysRevPhysEducRes.15.020138.

Sedayu, A., Herpratiwi, Yulianti, D., & Distrik, I. W. (2024). Impact of OER-Assisted Problem-Based Learning on Creative Thinking and Self-Efficacy in Physics Education. *Qubahan Academic Journal* 4(3):748–62. doi:10.48161/qaj.v4n3a817.

Setiati, N., & Jumadi. (2023). Development of E-Worksheet Problem Based Learning Model on Work and Energy to Improve Students' Physical Cognitive Abilities in Terms of Mathematical Representations and Verbal Representations. *Jurnal Penelitian Pendidikan IPA* 9(1):93–98. doi:10.29303/jppipa.v9i1.1757.

Shishigu, A., Hailu, A., & Anibo, Z. (2017). Problem-Based Learning and Conceptual Understanding of College Female Students in Physics." *EURASIA Journal of Mathematics, Science and Technology Education* 14(1). doi:10.12973/ejmste/78035.

Siew, N. M. & Mapeala, R. (2017). The Effects Of Thinking Maps-Aided Problem-Based Learning On Motivation Towards Science Learning Among Fifth Graders. *Journal of Baltic Science Education* 16(3):379–94. doi:10.33225/jbse/17.16.379.

Sugiyono. (2017). Metode Penelitian Kuantitatif, Kualitatif, dan R&D. Bandung: CV. Alfabeta.

Suhirman, & Prayogi, S. (2023). Problem-Based Learning Utilizing Assistive Virtual Simulation in Mobile Application to Improve Students' Critical Thinking Skills. *International Journal of Education and Practice* 11(3):351–64. doi:10.18488/61.v11i3.3380.

Sujanem, R., & Suwindra, I. N. P. (2023). Problem-Based Interactive Physics E-Module in Physics Learning Through Blended PBL to Enhance Students' Critical Thinking Skills. *Jurnal Pendidikan IPA Indonesia* 12(1):135–45. doi:10.15294/jpii.v12i1.39971.

Sulaiman, F., Rosales, J.R., J., J., & Kyung, K. (2023). The Effectiveness Of The Integrated Stem-Pbl Physics Module On Students' Interest, Sense-Making And Effort. *Journal of Baltic Science Education* 22(1):113–29. doi:10.33225/jbse/23.22.113.

Sulasih Sarwanto, & Suparmi. (2018). Physics Learning with Metacognitive Approach through Problem-Based Learning (PBL) and Reciprocal Learning (RL) Model Viewed from Students' Critical Thinking Skill. *International Journal of Pedagogy and*

Teacher Education 2:9. doi:10.20961/ijpte.v2i0.19896.

Sunarti, T., Suprapto, N., Prahani, B., K., Satriawan, M., & Rizki, I., A. (2024). Online Problem-Based Learning and 3D Digital Books to Improve Pre-Service Teachers' Scientific Literacy. *International Journal of Evaluation and Research in Education (IJERE)* 13(5):3139. doi:10.11591/ijere.v13i5.29835.

Suryanti, E. & Festiyed. (2023). Development of Student Worksheets Based on Problem Based Learning Models with Video-Assisted Scientific Approaches to Improve Science Process Skills. *Jurnal Penelitian Pendidikan IPA* 9(7):5673–81. doi:10.29303/jppipa.v9i7.3672.

Tipler, P. A. (2001). Fisika Untuk Sains dan Teknik Jilid 2(Terjemahan). Edisi. Ketiga. Jakarta: Erlangga.

Wartono, W., Diantoro, M., & Bartlolona, J., R. (2018). Influence of Problem Based Learning Learning Model on Student Creative Thinking on Elasticity Topics A Material. *Jurnal Pendidikan Fisika Indonesia* 14(1):32–39. doi:10.15294/jpfi.v14i1.10654.

Wijaya, T., P., Mundilarto, & Wilujeng, I. (2024). Development of Problem Based Learning Collaborative (PBL-C) Physics E-Worksheet to Improve Student Problem Solving and Collaboration Skills. *Jurnal Penelitian Pendidikan IPA* 10(1):47–54. doi:10.29303/jppipa.v10i1.5284.

Yanto, F., Festiyed, & Enjoni. (2021). Problem Based Learning Model For Increasing Problem-Solving Skills In Physics Learning. *JIPF (Jurnal Ilmu Pendidikan Fisika)* 6(1):53. doi:10.26737/jipf.v6i1.1870.

Yuberti, Latifah, S., Anugrah, A., Siregar, A., Misbah, Jermsittiparsert, K. (2019). Approaching Problem-Solving Skills of Momentum and Impulse Phenomena Using Context and Problem-Based Learning. *European Journal of Educational Research* volume-8-2019(volume8-issue4.html):1217–27. doi:10.12973/eu-jer.8.4.1217.