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Problem-based learning (PBL) as an effective solution to enhance understanding of physics concepts: A systematic literature review

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Abstract: Understanding physics concepts remains a focal point of education, continually researched and sought for appropriate solutions, especially in teaching strategies. The teaching strategies employed vary greatly in influencing students' understanding of concepts. The aim of this research is to identify effective solutions in enhancing students' understanding of physics concepts, based on data obtained from various relevant journals from 2010 to 2022. This study was conducted using the Systematic Literature Review (SLR) method, utilizing databases such as ERIC, Journal of Education Research, British Education Journal, and other journals indexed by SINTA to identify, review, evaluate, and interpret available research. The results indicate that an effective teaching strategy to enhance students' understanding of concepts is Problem-Based Learning (PBL).
Keywords: understanding of concepts; Systematic Literature Review (SLR); Problem-Based Learning (PBL)

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Introduction

Understanding concept issues remain a focus continuously researched in educational development. Conceptual understanding is the fundamental asset for learners to think logically (Banda & Nzabahimana, 2021; Docktor et al., 2016), provide explanations of a material concept using various representations (Bozdaq & Turkoguz, 2021), classify or group a phenomenon as an example or non-example of interpreting an abstract idea (Taqwa et al., 2020), formulate a concept into mathematical language and apply it to solve complex problems (Andayani et al., 2018), and apply concepts in everyday life (Mills, 2016). Conceptual understanding also plays a crucial role in advanced thinking such as critical and creative thinking (Astutik et al., 2020; Dholo et al., 2019; Fatmawati et al., 2019)

Research has revealed that misconceptions in physics concepts frequently occur among learners, such as in kinematics (Bollen et al., 2016; Canlas, 2016; Dianningrum et al., 2020; Kane et al., 2016; Klein et al., 2017; Pendrill, 2020; Sutopo et al., 2020; Taqwa & Rivaldo, 2018); Newtonian dynamics (Alrsaʾi et al., 2020; Ergin, 2016; Garcia-Lladó & López, 2020; Kaniawati et al., 2019; Lo & Beichner, 2019; Low & Wilson, 2017; Nieminen et al., 2017; Pendrill, 2020; Zahopoulos, 2016); fluida (Althaf & Region, 2020; Jamaludin & Batlolona, 2021; Marciotto, 2016; Pamungkas et al., 2019; Wuttiprom, 2018); (Batlolona et al., 2020; Hubenthal, 2018; Mustofa, 2018; Rosiqoh et al., 2020; Saʾdiyah et al., 2017; M. R. A. Taqwa et al., 2019); kelistrikan (Hamid et al., 2017; Ismail et al., 2019; Saputro et al., 2018; Şenyiğit, 2021; Suciatmoko et al., 2018). Misconceptions or misconceptions are concepts derived from linking learners' experiences, strongly held or believed, but different from expert concepts (Kaniawati et al., 2019; Kola & State, 2017). Misconceptions can occur due to errors in interpreting material (Kurniawan et al., 2019). Physics learning that overlooks misconceptions can cause learners difficulty in learning and result in low learning achievements (Asikainen et al., 2020; Fatmawati et al., 2019). Moreover, unchecked misconceptions will impact less accurate understanding beliefs and continue to be carried over to subsequent educational levels (Ceuppens et al., 2018; Kaewkhong, 2020; Wartono et al., 2018).

In addition to factors within learners themselves, the use of learning models that are not tailored to the characteristics of learning needs also affects. Teachers use monotonous learning models, namely one teacher-centered learning model and lecture-based learning methods (Emalliana, 2017; Matsuyama et al., 2019). Physics learning models that are informative and non-contextual are one of the reasons learners struggle to understand the material concepts being studied (Kola & State, 2017; Reyza Arief Taqwa et al., 2020). Therefore, an appropriate strategy is needed to help learners understand concepts through contextual problem-based learning.

Problem-Based Learning (PBL) is one learning strategy that focuses on learners (student-centered learning) by using contextual problems to help learners understand the material concepts being studied. Problem-based learning is a learning model with stages of the scientific method (Polyiem & Nuangchalerm, 2022). This model directs learners to solve a problem until they acquire knowledge and skills in problem-solving (Polyiem & Nuangchalerm, 2022). This model directs learners to solve a problem until they acquire knowledge and skills in problem-solving (Andayani et al., 2018; Kolmos et al., 2020a). In the PBL learning model, learners are required to be active, creative, and independent in solving the problems they face based on the knowledge and experiences they possess (Nasution et al., 2019). In addition, in PBL learning, learners are required to analyze problems and create reports as benchmarks for the abilities of learners (Alt & Raichel, 2022; Sholihah & Lastariwati, 2020). This learning is not teacher-centered; the teacher's role is as a facilitator by guiding and assisting in the learning process (Hidayati et al., 2021; Hung, 2009). The final outcome of PBL learning is that learners can connect experiences with their knowledge more meaningfully (Kanyesigye et al., 2022).

The success of the PBL learning model at various educational levels has been extensively studied and proven by research from various countries (Hallinger, 2020; Korkmaz, 2021), but systematic studies are still relatively few. Therefore, systematic research reviewing journal articles related to the effectiveness of PBL strategies for learners' conceptual understanding is needed, with the aim of identifying effective PBL solutions in improving understanding of physics concepts and their distribution in education through a systematic literature review.

Method

The research was conducted using systematic review techniques, utilizing various references from journal articles and proceedings. The identification stage involved searching various references taken from main databases, namely ERIC, and other sources such as the European Journal of Education Research (Eu-JER), British Educational Journal Research (BERA), Journal of Physics: Conference Series, and SINTA Journals with accreditations 1 – 3. The total number of articles from the main ERIC database was collected using the keyword "problem-based learning," selected within the last 10 years, resulting in the number of articles (n = 2052). These were further narrowed down to "problem-based learning" and "conceptual understanding," resulting in a total of (n = 22) research data. Articles from other sources were added using the same keywords, obtained from Eu-JER (n = 43); Journal of Physics: Conference Series (n = 14); BERA (n = 7); and SINTA Journals with accreditations 1 – 3 (n = 4). The total articles obtained were 65, and after eliminating duplicates, the final identification stage yielded a total of (n = 60).

In the identification stage, the total articles (n = 60) were further screened based on inclusion and exclusion criteria (screening) according to Table 1, to obtain research data relevant to the learning objectives. It was found that (n = 3) research data did not indicate variable suitability with the research objectives, resulting in a final research data count of (n = 57). These data were then assessed for eligibility to obtain appropriate supporting data. From the research data (n = 57), (n = 14) were deemed ineligible because their results did not indicate the required variables for this study. The final outcome yielded (n = 43) research article data used in the systematic literature review. The data collection process leading to the final data is clearly illustrated in Figure 1.

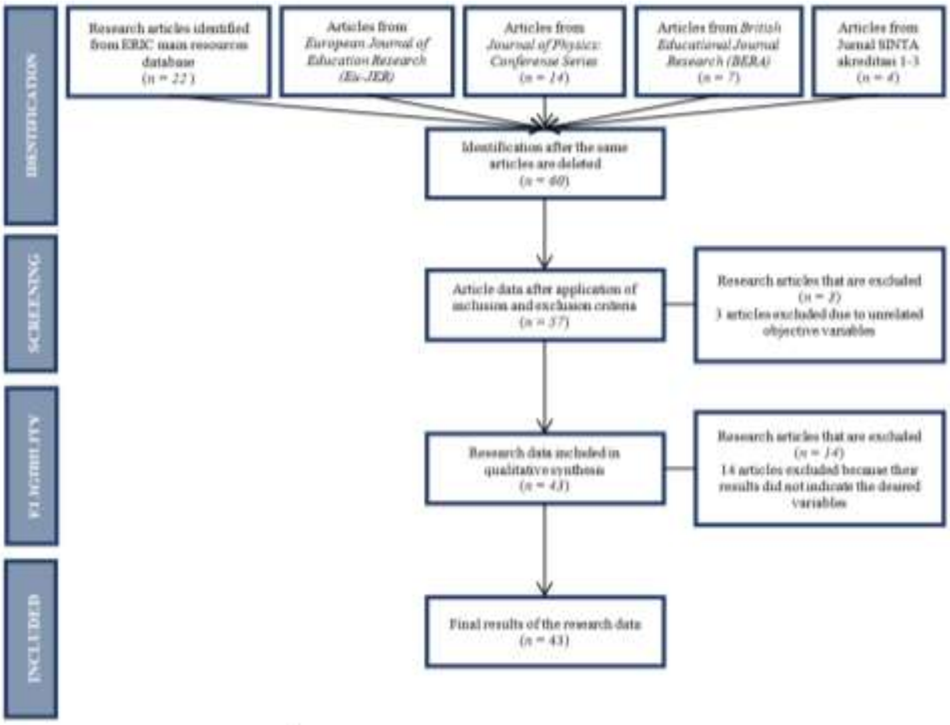

Figure 1. Systematic Literature Review Stages

Table 1. Inclusion and Exclusion Criteria

Inclusion Criteria	Literature review in the form of journal articles Articles relevant to the research topic, including: a. Learning with Problem-Based Learning (PBL) model b. Conceptual Understanding c. Physics Learning Open access (free) Articles published between 2010-2022 Articles published using international languages
Exclusion Criteria	Literature studies other than journals such as papers, theses, and books Journal articles unrelated to the topic Not open access or requiring payment Articles published outside the timeframe of 2010-2022 Articles not published in international languages

Results and Discussion

Understanding is the primary goal of learning implementation (Uluçınar, 2021; Wiggins & McTighe, 2005). Understanding is a prerequisite for higher-order cognitive abilities (Kola & State, 2017; Nieminen et al., 2012a). Bloom classified understanding into three categories: translation understanding, interpretation understanding, and extrapolation understanding (I. M. Dwi et al., 2013). Translation understanding is the lowest level of these three categories, which is the ability to translate, for example, translating a term into its true meaning. Interpretation understanding is the ability to connect previous material with subsequent material, representing a second-level understanding. Third-level understanding, extrapolation understanding, or predictive ability, expects learners to see beyond the written, make predictions about consequences, or broaden perceptions in terms of time, dimension, cases, or problems (Suhendar & Ekayanti, 2018).

Concepts are crucial for learners. A concept is an idea based on relevant experiences that can be generalized, forming a concept (Taqwa, 2017; Taqwa & Pilendia, 2018). Concepts help learners classify, analyze, and connect the main subject structures in school (Docktor & Mestre, 2014; Nieminen et al., 2012b). Understanding concepts is a process, method, or action to understand or know in detail the learned concepts (Anggrayni & Ermawati, 2019; Syaharudin et al., 2015; Tural, 2015). Understanding learners' concepts is one of the cognitive learning outcomes obtained through the learning process. Conceptual understanding, in general, can be interpreted as learners' ability to understand concepts, express concepts in their own language, and connect these concepts to each other in daily life (Fariyani et al., 2017; Hamid et al., 2017; Purwaningtias & Putra, 2020). Learners' independence in their own abilities influences how they apply concepts they have understood in their daily lives (Eriana et al., 2018). Learners build concepts in their minds from their experiences in school education or daily activities (Kaltakci-Gurel et al., 2017). Because learners have different experiences, they may have correct or incorrect concepts of scientific conceptions. Learners express their concepts independently of scientifically recognized concepts related to their science lessons.

Conceptual understanding is the most important part of learning, both in solving problems in the learning process and in the surrounding environment. The ability to understand concepts is the foundation of thinking in solving various problems (Irwandani & Rofiah, 2015). The indicators of mathematical conceptual understanding are: (a) connecting concepts that have been and will be learned, (b) classifying objects based on these concepts; (c) applying concepts algorithmically; (d) providing examples according to real-life concepts (e) representing concepts in mathematical forms; (f) linking with mathematical concepts; (g) developing the necessary conditions and a concept (Rosmawati & Sritresna, 2021). Learners are said to achieve conceptual understanding with indicators including being able to know and remember physics concepts, being able to describe the characteristics of concepts according to the Bloom Taxonomy sequence, being able to connect specific facts with physics material, and being able to solve problems related to concepts (Lasut & Seleky, 2017). Several indicators are used by researchers to measure the extent of conceptual understanding mastered by learners.

Problem-Based Learning (PBL)

Problem-Based Learning (PBL) is a learning approach based on real and relevant problems for students to gain realistic learning experiences (Kilinska & Ryberg, 2019). The PBL model involves students in solving realistic problems using scientific methods so that they can recognize, organize, redevelop, and transform their initial knowledge through interactions between the environment, classroom activities, experiences, and interactions with other students (Korkmaz, 2021). Students are required to be active and creative during the learning process as the PBL model is student-centered. This learning model demands cooperation or collaboration among students to solve problems from various perspectives, thereby enhancing students' learning abilities to face challenges in real life (Gorghiu et al., 2015). In problem-based learning, teachers have a role in guiding students to discover, verify, and build their own knowledge so that the knowledge they possess is more meaningful and stored in their long-term memory (Taqwa et al., 2019).

The characteristics of the PBL model are as follows: (a) Student-centered learning, (b) Collaborative learning among students, (c) Teachers act as moderators and facilitators, (d) Training skills in problem-solving, (e) Independent learning assists students in acquiring new knowledge. The PBL learning model has advantages and disadvantages such as 1) training students to solve problems in real situations, 2) the ability to build knowledge from collaborative learning activities, 3) the learning difficulties experienced by students can be solved together (Rerung et al., 2017). While the disadvantages include: 1) Problem-based learning cannot be applied to all subjects, and 2) in a class, there are several student characteristics, making it difficult to distribute tasks for the application of the PBL model (Dwi & Anitah, 2018).

Science education that implements the PBL model aims to improve science process skills and physics learning outcomes (Fidan & Tuncel, 2019; Kilinska & Ryberg, 2019; Phunaploy et al., 2021), conceptual understanding (Amanda et al., 2022; Nangku & Rohaeti, 2019; Uliyandari et al., 2021), and problem-solving abilities & interest in learning physics (Herlinda et al., 2017; Shishigu et al., 2018). Steps to consider in implementing PBL in science education are (1) identifying terms and concepts that cannot be understood indirectly, (2) defining the problem, (3) analyzing the problem, (4) making a systematic inventory based on step 3, (5) formulating learning objectives, (6) gathering additional information, and (7) synthesizing the newly obtained information (Jamiat, 2018).

Targets of PBL in Improving Conceptual Understanding of Physics

Based on several articles that have met the criteria, there are various research objectives in presenting learning with the problem-based learning model to enhance students' understanding. The diversity of research objectives aims to measure the level of understanding and thinking abilities of students based on their educational level. The following data on research objectives by several researchers are presented in Figure 2.

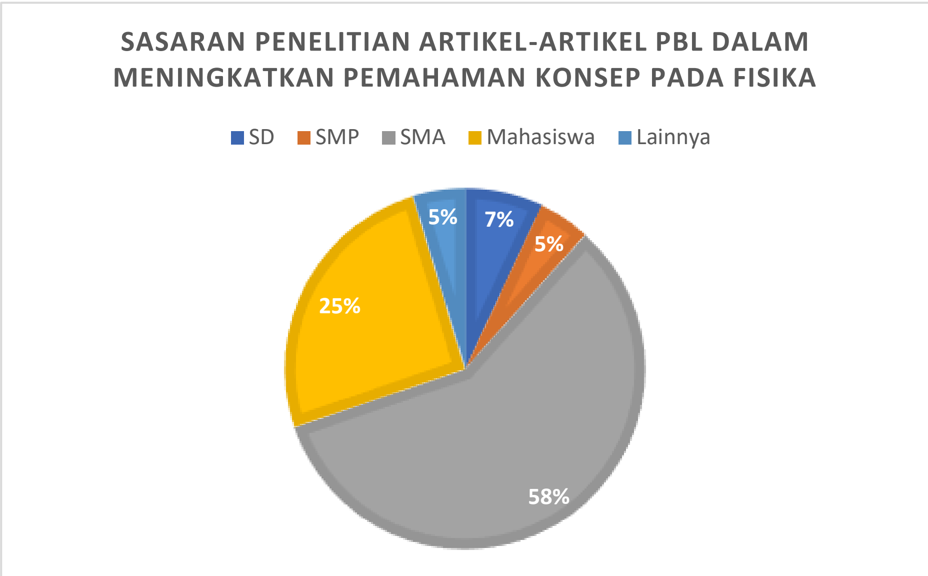

Figure 2. Research Target according to the criteria "PBL Learning to Improve Conceptual Understanding of Physics"

Based on Figure 2, the differences in educational levels in applying the PBL model to enhance conceptual understanding are adjusted to the achievement of competencies and thinking abilities of students. For example, research that has been conducted on the effectiveness of the PBL model with cartoon concepts in teaching STEM and science to elementary school students shows that the application of the PBL model assisted by cartoon media is effective in enhancing students' understanding of science (İnel & Balım, 2013). Research at the junior high school level on the effectiveness of PBL learning in science education explains that the implementation of the Problem-Based Learning model in the 2013 curriculum resulted in an improvement in the understanding of the concept of pressure for aspects of translation, interpretation, and exploration (Ahied & Ekapti, 2020). Furthermore, at the senior high school level, it was found that there was a higher percentage of results compared to other levels regarding the application of the PBL model with interactive multimedia to improve students' understanding of thermodynamics concepts (Husein et al., 2019). The research obtained results that the application of PBL learning with interactive multimedia containing investigative videos and equipped with questionnaires can activate students to experiment virtually, formulate hypotheses, collect, analyze data, describe each Carnot cycle process, and draw conclusions. Research at a higher level, namely university students, on the Effectiveness of the PBL Model in the

Academic Achievement of the "Basic Physics I" Course. The application of the PBL model can increase students' understanding of the basic principles of classical physics phenomena (Suarez, 2017).In literature studies on integration levels, elementary, junior high, and high school regarding the analytical approach to understanding collaborative inquiry in PBL learning show that PBL can enhance students' intellectual effectiveness by integrating learned or other learning (Hallinger, 2020).

Results of Students' Conceptual Understanding from the Application of PBL in Learning

Based on the collected literature, there are 31 articles focusing on learning with Problem-Based Learning (PBL) in physics education. PBL learning brings about conceptual changes in Newton's laws, where an increase in conceptual understanding can be measured by the results of linking new material to previously learned material, being able to solve problems with different methods, and being able to learn independently. From the increased understanding of experimental class concepts, there is evidence of high cognitive change for students (Loyens et al., 2015). Overall, the implementation of Problem-Based Learning (PBL) influences conceptual understanding, particularly in physics learning, such as in the topic of pressure (Ahied & Ekapti, 2020), the Doppler effect (Jamaludin et al., 2022), mechanical waves (Kanyesigye et al., 2022), Newton's laws (Loyens et al., 2015), Newtonian mechanics (Sahin, 2010b), classical physics (Suarez, 2017), modern physics (Sulaiman, 2010), elasticity and Hooke's law (Taqwa et al., 2019), Newtonian mechanics (Sahin, 2010b), magnetism (Choden & Kijkuakul, 2020), physics learning (Shishigu et al., 2018), science education (Uliyandari et al., 2021).

The PBL model leads to an improvement in students' conceptual understanding with teachers acting as facilitators. PBL model-assisted Web-Assisted learning influences students' conceptual understanding in the experimental class on harmonic vibration material. The research results indicate that to improve students' conceptual understanding, they must discover the concepts to be learned themselves, and educators only serve as facilitators; students must also be involved in accessing and operating Web-Assisted media independently (Zahro et al., 2019). Students are required to work independently in solving problems by analyzing, evaluating, and synthesizing information from various sources and explaining it according to their understanding. Students are said to understand the concept if they can construct meaning from learning messages, whether oral, written, or graphic, conveyed through teaching, books, or computer screens (Sholihah & Lastariwati, 2020; Simanjuntak et al., 2021).

Based on 12 other literatures, the application of Problem-Based Learning (PBL) is found to be associated with other variables such as assessment, communication, Learning Analyst, web, and game-based learning. Research related to PBL combined with the PROFILE project variable in students emphasizes communication between teachers and students and problem-solving on science concepts (Gorghiu et al., 2015), PBL-based handouts to improve self-directed learning and conceptual understanding in rotational dynamics (Haji et al., 2015), developing a PBL-based model on wave materials (Herayanti et al., 2018), integrating PBL with interactive multimedia on thermodynamics materials (Husein et al., 2019), developing learning media with cartoons integrated with PBL methods in science learning (İnel & Balım, 2013), integrating PBL with multiple representations in science concepts (Simanjuntak et al., 2021), integrating PBL into Blended Learning on thermodynamics materials (Marnita et al., 2020), integrating PBL with e-handouts assisted by PhET simulations on momentum-impulse materials (Rahmawati et al., 2020), integrating Context-PBL on momentum and impulse materials (Yuberti et al., 2019), integrating PBL with Web-Assisted on harmonic vibration materials (Zahro et al., 2019), PBL-based physics learning web for vocational schools on temperature and heat materials (Ariyana et al., 2019), PBL integrated models with local wisdom in physics learning (Fauzana et al., 2019), integrating AR into PBL activities for physics subjects (Fidan & Tuncel, 2019), PBL with individual strategy in learning (Kardoyo et al., 2020), implementing systemic-PBL in science learning (Kolmos et al., 2020b), PBL in elementary school on simple electrical circuit materials (Şenyiğit, 2021).

PBL is also effective when associated with other variables and not just in physics materials. The development of Moodle-based PBL can improve students' conceptual understanding of wave materials. Indicators that affect conceptual understanding include an attractive Moodle media design that provides a fun and non-boring learning atmosphere and students' activity in finding material equations and completing various tasks independently (Herayanti et al., 2018).Other research with the implementation of PBL with self and peer assessment in teacher training programs (Alt & Raichel, 2022), integrating the CS-PBL model with SIPEJAR assisted by post-COVID-19 pandemic learning physiology (Amanda et al., 2022), PBL enhances intellectual structure effectiveness and can be integrated with other active learning domains (Hallinger, 2020), implementing blended learning media based on Problem-based learning for students in improving learning achievements in Islamic education (Hamzah et al., 2022), PBL approach in engineering and architecture learning in improving communication skills (Keenahan & McCrum, 2021), linking Learning Analyst with PBL (Kilinska & Ryberg, 2019), applying PBL from a Christian perspective (Lasut & Seleky, 2017), the effectiveness of guided PBL models on statistics (Leppink et al., 2014), integrating PBL with an internet platform for vocational high school students (Lou et al., 2010), PBL in enhancing verbal communication skills and conceptual understanding in reaction rate topics (Nangku & Rohaeti, 2019), PBL combined with gaming in learning (Saleh et al., 2022), PBL in problem-solving abilities in vocational high schools (Sholihah & Lastariwati, 2020). The results of the article review with a systematic literature review method are summarized as shown in Table 2.

Table 2. Results of literature review articles on improving conceptual understanding from the application of PBL

Research	Focus of Research	Target	Method	Material	Country	Relevant Findings
(Ahied & Ekapti, 2020)	PBL, Conceptual Understanding, Pressure	Junior High School	Quantitative	Natural Science	Ethiopia	The implementation of problem-based learning in the 2013 curriculum resulted in an increased understanding of concepts for translating, interpreting, and extrapolating the concept of pressure.
(Alt & Raichel, 2022)	PBL, *Self and Peer Assessment*	Senior High School	Quantitative	Physics	Israel	PBL is more prominent and effective in improving conceptual understanding based on peer and self-assessment.
(Amanda et al., 2022)	*Complex Science-Problem-based learning*	University Students	R&D	Physics	Indonesia	The CS-PBL model assisted by SIPEJAR is considered valid, practical, and effective in improving students' concept mastery during the post-COVID-19 pandemic period.
(Andayani et al., 2018)	Conceptual Understanding and Critical Thinking	University Students	Quantitative	Physics-Chemistry	Indonesia	Levels of conceptual understanding and critical thinking increase positively after the application of PBL in learning.
(Aryani et al., 2019)	*Web-bases Problem-based learning*	University Students	R&D	Temperature and Heat	Turkey	The development of Physics Education Learning Web for vocational high school students on temperature

Research	Focus of Research	Target	Method	Material	Country	Relevant Findings
						and heat is proven effective in assisting students' conceptual understanding in online learning accessible anytime and anywhere.
(Choden & Kijkuakul, 2020)	PBL and *Scientific Argumentation*	Senior High School	Qualitative	Basic Genetics	Thailand	The combination of PBL with scientific argumentation effectively improves students' understanding of basic genetics.
(Fauzana et al., 2019)	PBL, Local Wisdom, Student Competence	Senior High School	Quantitative	Physics	Indonesia	Physics learning with a PBL model integrated with local wisdom is effective in improving students' conceptual competence.
(Fidan & Tuncel, 2019)	AR-based PBL, Learning Achievement, and Positive Attitude	Elementary School	*Mixed-Method*	Gravitasi	Turkey	Integration of AR into PBL activities enhances students' learning achievements and fosters positive attitudes towards physics subjects.
(Gorghiu et al., 2015)	PBL, Conceptual Understanding, and Problem Solving	Junior High School	Study of literature	Natural Science	Romania	PBL learning with the PROFIL project emphasizes that the quality of communication between teachers and students is excellent. Teacher and student feedback is positive, with significant achievements in students' understanding of science concepts.
(Haji et al., 2015)	PBL, Handout, and Conceptual Understanding	Senior High School	Quantitative	Rotational Dynamics	Indonesia	PBL learning and handouts can improve students' self-directed learning and conceptual understanding in rotational dynamics.
(Hallinger, 2020)	PBL and Intellectual Structure	Elementary school, Junior High School, & Senior High School	Literature Study	Physics	Thailand & Africa	PBL enhances the effectiveness of intellectual structure and can be integrated with other active learning domains.
(Hamzah et al., 2022)	*Blended Learning,* PBL	Senior High School	R&D	Physics	Indonesia	The effectiveness of using blended learning media based on Problem-based learning for students in

Research	Focus of Research	Target	Method	Material	Country	Relevant Findings
						improving learning achievements.
(Herayanti et al., 2018)	Moodle, PBL, Conceptual Understanding	Senior High School	Quantitative	Waves	Indonesia	Development of Moodle-based PBL improves students' conceptual understanding of wave materials.
(Husein et al., 2019)	PBL, Interactive Media, Conceptual Understanding	Senior High School	R&D	Thermodynamics	Indonesia	PBL learning with interactive multimedia effectively improves students' mastery of thermodynamics concepts.
(İnel & Balı m, 2013)	Learning Media (Cartoon) based Problem-based learning & Conceptual Understanding	Elementary School	R&D	Expansion	Turkey	Learning media with cartoon assisted by Problem-based learning is an effective method for secondary school students to enhance their understanding of science.
(Dwi & Anitah, 2018)	PBL and Conceptual Understanding	Elementary School	Quantitative	Natural Science	Indonesia	PBL can effectively improve students' conceptual understanding of physics.
(Jamaludin et al., 2022)	PBL and Conceptual Understanding	Senior High School	Quantitative	Doppler Effect	Indonesia	The research results show that PBL enhances students' conceptual understanding of the Doppler effect topic.
(Kanyesigye et al., 2022)	PBL and Conceptual Understanding	Senior High School	Quantitative	Physics	Uganda	PBL learning practices provide an increase in conceptual understanding of mechanical wave materials for prospective physics teachers.
(Keenahan & McCrum, 2021)	PBL and Communication	University Students	*Mixed-Method*	Physics-Engineering (Force and Equilibrium)	Irlandia	The PBL approach supports the improvement of learning processes and communication skills among teams.
(Kolmos et al., 2020b)	*Systemic* PBL	University Students	Quantitative	Physics	Denmark	Consistently implementing the systemic PBL is higher in preparing scientific conceptual competencies and self-assessment independence.
(Lasut & Seleky, 2017)	PBL, Conceptual Understanding, Christian Perspective	Senior High School	Quantitative	Physics	Indonesia	The problem-based learning application can enhance conceptual

Research	Focus of Research	Target	Method	Material	Country	Relevant Findings
						understanding based on the Christian perspective.
(Leppink et al., 2014)	*Guided in Problem-based learning*	University Students	Quantitative	Physics	Netherlands	Guided PBL tends to improve conceptual understanding more than classical PBL models. Guided PBL also increases students' awareness of the value and benefits of the learning process.
(Lou et al., 2010)	PBL and Knowledge Transfer	Senior High School	Quantitative	Physics-Engineering	USA	Vocational high school students' ability to transfer knowledge significantly increases through solving conceptual problems on the internet platform PBL.
(Loyens et al., 2015)	PBL, Conceptual Understanding Change	Senior High School	Quantitative	Newton's Laws	USA	PBL learning brings about positive changes in conceptual understanding in Newton's laws topics
(Simanjuntak et al., 2021)	PBL with multiple representations, Conceptual Understanding	Senior High School	Quantitative	Heat Temperature	Indonesia	PBL model with multiple representations can enhance conceptual understanding of science subjects.
(Marnita et al., 2020)	PBL and *Blended Learning*	Senior High School	Quantitative	Thermodynamics	Indonesia	Implementing PBL in Blended Learning can enhance students' critical thinking skills, especially in thermodynamics.
(Nangku & Rohaeti, 2019)	PBL, Conceptual Understanding, Verbal Communication Skills	Senior High School	Quantitative	Chemistry	Indonesia	PBL has a positive effect on students' conceptual understanding, as demonstrated through oral communication skills.
(Rahmawati et al., 2020)	PBL, Conceptual Understanding	Senior High School	R&D	Momentum-Impulse	Indonesia	E-handouts assisted by PhET simulations based on a problem-based learning (PBL) model about the law of momentum conservation and collisions to train conceptual understanding.
(Sahin, 2010a)	*Problem-based learning*	University Students	Quantitative	Physics	Turkey	Analysis shows that classes applying the PBL model achieve significantly higher conceptual understanding than traditional classes, as

Research	Focus of Research	Target	Method	Material	Country	Relevant Findings
						seen from the significant increase from pretest to posttest.
(Sahin, 2010b)	PBL, Conceptual understanding, Epistemological Beliefs about Physics	University Students	Quantitative	Physics	Turkey	PBL learning has been effective in epistemological beliefs about physics and conceptual understanding of Newtonian Mechanics.
(Saifullah et al., 2017)	PBL, Conceptual Understanding, Problem-solving	Senior High School	Quantitative	Momentum-Impulse	Indonesia	PBL enhances students' understanding and skills in applying vectors.
(Saleh et al., 2022)	PBL and *Game-Based Learning*	Elementary School	Qualitative	Natural Science	USA	Collaborative PBL can be used to design learning provided in games to enhance students' communication and conceptual understanding.
(Şenyiğit, 2021)	*Problem-based learning*	University Students	Quantitative	Electrical Circuits	Turkey	Problem-based learning is more effective in improving conceptual understanding and addressing misconceptions than lecture-based learning.
(Serevina et al., 2018)	PBL, Conceptual Understanding, Module	Senior High School	R&D	Heat Temperature	Indonesia	Problem-Based Learning (PBL) based electronic modules as information and communication technology implementations are effective in improving conceptual understanding.
(Shishigu et al., 2018)	*Problem-based learning*	Senior High School	Quantitative	Physics	Ethiopia	Based on research, it is recommended to implement PBL in schools because it greatly helps students to observe the relationship between theory and practice, enhances learning motivation, and understanding of concepts.
(Sholihah & Lastariwati, 2020)	PBL, Critical thinking, and Problem-solving abilities	Senior High School	R&D	Physics	Indonesia	The application of PBL can improve critical thinking skills and

Research	Focus of Research	Target	Method	Material	Country	Relevant Findings
						problem-solving abilities in the material.
(Suarez, 2017)	PBL, Academic Performance Improvement	University Students	Quantitative	Kinematics and Dynamic Fluids	Peru	PBL learning contributes to understanding the basic principles of classical physics phenomena "Physics I" compared to conventional learning.
(Sulaiman, 2010)	PBL, Conceptual Understanding, Connection of various materials	Prospective Teachers	Qualitative	Physics	New Zealand	PBL learning in understanding concepts in Modern Physics/Physics content knowledge and sharing communication knowledge.
(Taqwa et al., 2019)	*Problem-based learning*& Conceptual Understanding	Senior High School	Quantitative	Elasticity	Indonesia	The implementation of Problem-based learning models has an influence on the improvement of elasticity concepts and Hooke's law. With the Problem-based learning model, it encourages students to be more active in learning and helps students understand physics better.
(Uliyandari et al., 2021)	PBL, Conceptual Understanding, and Critical Thinking Abilities	University Students	Quantitative	Natural Science	Indonesia	The implementation of PBL learning affects students' conceptual understanding and critical thinking abilities because of the presentation of real problems that stimulate students to interpret and understand them.
(Yuberti et al., 2019)	PBL, Problem-solving, Conceptual Understanding	Senior High School	Quantitative	Momentum-Impulse	Indonesia	The C-PBL model can improve students' problem-solving skills in physics, students' communication skills, students' confidence in learning, and improve students' conceptual understanding of physics subjects on momentum impulse materials.
(Yulianti, 2016)	PBL, character and conceptual understanding	Senior High School	Quantitative	Physics	Indonesia	The implementation of PBL learning with worksheets can improve students' understanding and monitor the

Research	Focus of Research	Target	Method	Material	Country	Relevant Findings
						development of students' character.
(Zahro et al., 2019)	PBL, Web-Assisted, Conceptual Understanding	Senior High School	*Mixed-Method*	Simple Harmonic Motion	Indonesia	PBL model learning assisted by Web-Assisted influences students' conceptual understanding positively in experimental classes on harmonic vibration materials.

Conclusion

Problem-Based Learning (PBL) is a learning model that emphasizes the active participation of students in solving scientific problems with the learning syntax: (1) problem orientation; (2) organizing students for learning; (3) guiding individual and group investigations; (4) developing and presenting results; and (5) analyzing and evaluating problem-solving processes. PBL is applied with the aim of providing experiences for students to solve real problems in the subjects being studied. The results of several journal reviews show that Problem-Based Learning is effectively applied in physics learning to improve students' conceptual understanding from various levels, ranging from elementary to senior high school. Thus, with the Problem-Based Learning model, it is hoped that it can be applied to continuously solve students' conceptual understanding problems.

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