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Improving Students' Learning Outcomes in Problem Solving Through Problem Solving Method: Systematic Literature Review

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Abstract: Problem-solving must be owned by students in learning process, which is the ability of students to solve physics problems effectively. Ineffective problem solving skills will impact on students' learning outcomes. Then, structured and appropriate efforts are needed to improve students' ability to solve physics problems. The particular study employed the Systematic Literature Review (SLR) method, which is designed to systematically identify, categorize, review, evaluate, and interpret relevant journal articles based on criteria. The SLR approach followed a structured and replicable process that ensures transparency and rigor in synthesizing existing research following the research objectives. The findings indicated that the difficulties experienced by students in learning physics are caused by several factors, such as: students' thoughts that always consider physics as a difficult subject, the use of inappropriate learning methods, and limited facilities and infrastructure to support learning. In addition, there are internal factors, such as students difficulties in adapting to learning and the differences in students' learning styles.

Keywords: Improvement, Problem-Solving, Student.

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INTRODUCTION

In this contemporary era, the global community demands individuals who have excellence in the field of science. Aisy et al., (2024) stated that the educational paradigm in the 21st century has undergone a fundamental shift, no longer emphasizing the mastery of memorization of subject matter in certain disciplines. Instead, the focus of education is now on developing essential life skills, high-level learning and thinking skills, information and communication technology literacy, and metacognitive and analytical abilities.

Purwanti & Manurung (2015) stated that the rapid progress of the times requires educators to exert greater effort in guiding students to adapt to these changes and master important learning skills effectively. In the field of education, especially physics, learning activities often follow the traditional learning model, where teachers often emphasize memorizing formulas and their direct application in problem-solving. However, the needs of today's students are much more complicated. This conventional approach often leads students to rely solely on memorizing formulas to solve problems without a true understanding of the underlying concepts. As a result, their capacity to solve problems independently and critically in physics tends to decrease.

According to Purwanti & Manurung (2015), students' proficiency in solving physics problems is directly correlated with their learning outcomes. Then, learning outcomes are likely to decrease if instructors only guide students to solve problems using existed methods, without allowing them to develop their ideas and understanding. Therefore, educators need to provide sufficient space for students

to demonstrate their abilities independently and encourage them in their personal reconstruction of concepts.

Previous research shows students' limited ability to solve physics problems, which is often reflected in their poor performance or outcomes in examinations. Furthermore, they have difficulty in completing student-worksheets, homework assignments, and formative and summative assessments. The inability to complete physics-related tasks correctly might negatively affect their final grades in semester exams (Purwanti & Manurung, 2015). Students' learning difficulties are influenced by two factors. First, internal factors come from the students themselves, such as memory, memorization skills, and creativity. Meanwhile, external factors come from the student's environment, including family, school, and community. These factors interact and collectively influence students' academic development and learning ability (Busnawir & Sani, 2018).

In this context, particularly in physics education, teachers need a knowledge base and skills that go beyond specific subjects to effectively assist students in facing various challenges (Nur, 2018). An important component is the ability to solve problems. Moreover, it has been proven to improve students' achievement (Sadiqin et al., 2017). Based on the findings of the literature review of Scopus-indexed journals, it indicated a low student learning outcome and are influenced by both internal and external factors. What specific internal and external factors significantly contribute to low student learning outcomes, especially in the context of problem solving

METHOD

A. Research Design

The study employed the systematic literature review (SLR) model. The method aims to systematically and measurably identify, sort, review, evaluate, and interpret relevant journals under the research focus. Moreover, the method follows several predefined systematic steps to ensure the validity and accuracy of the review results (Aulia et al., 2020).

The SLR research method is applied by conducting descriptive-qualitative analyses to the collected data. One of the important steps is to select and screen articles related to the topic "Efforts to Improve Students' Learning Outcomes in Problem Solving Through the Problem-solving Method." The data collection process conducted through documentation techniques, which means that each selected article will be documented regularly. In addition, this research sets some limitations, including analyzing journals published between 2018 and 2023. Moreover, the purpose of the particular research was to identify challenges and students' learning outcomes in the context of physics learning. Also, it presents the data in graphical form, as shown in figure 1, to clarify the research findings.

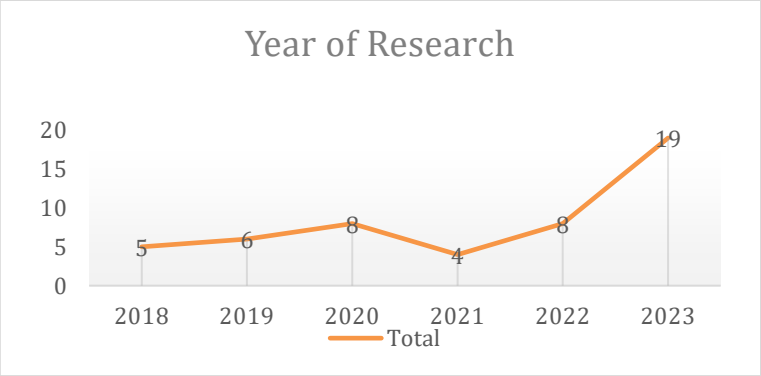

Figure 1. Graph of The Research Year

In 2018, 5 articles examined the results of improving problem solving in the problem-solving model. In 2019, the graph line increased where 6 articles discussed the results of improving problem solving in the problem-solving model. Then, 8 articles discussed the results of improving student problem solving in the problem-solving model in 2020. However, year of 2021 showed a decrease where only 4 articles matched the title of the research. But, in the following year of 2022, there was an increase in the graph, where 8 authors who researched and discussed student problem solving in physics and mathematics lessons. And, the graph of the number of studies increased dramatically where 19 authors who researched and discussed this problem in 2023.

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In sum, from 2018 to 2023, the number of authors who research or discuss physics problem solving in students is increasing from year to year, although experienced a decline in 2021. Therefore, it concluded that research on problem solving might never be finished, as shown in the graph 1 that research on problem solving continues to increase and develop as science develops, especially in the field of physics.

B. Inclusion and exclusion criteria

As a fundamental step in designing a study, the identification of sample criteria is crucial. These criteria inherently fall into two main, complementary categories: enabling criteria (inclusion) and excluding criteria (exclusion) (Rizal et al., 2024). In the inclusion and exclusion process, the study followed five steps. First, it searched for Scopus-indexed articles. Secondly, it looked for articles themes-related to learning difficulties and student learning outcomes. Third, it only considered scientific articles. Fourth, the study did not use term papers, theses, dissertations or review articles. Finally, the selected articles must be written in English.

C. Prism Flow Diagram

The prism method, also known as the prism flow diagram, was used to find Scopus articles before filtering, including year and material. Then, the articles are adjusted through four stages of customisation.

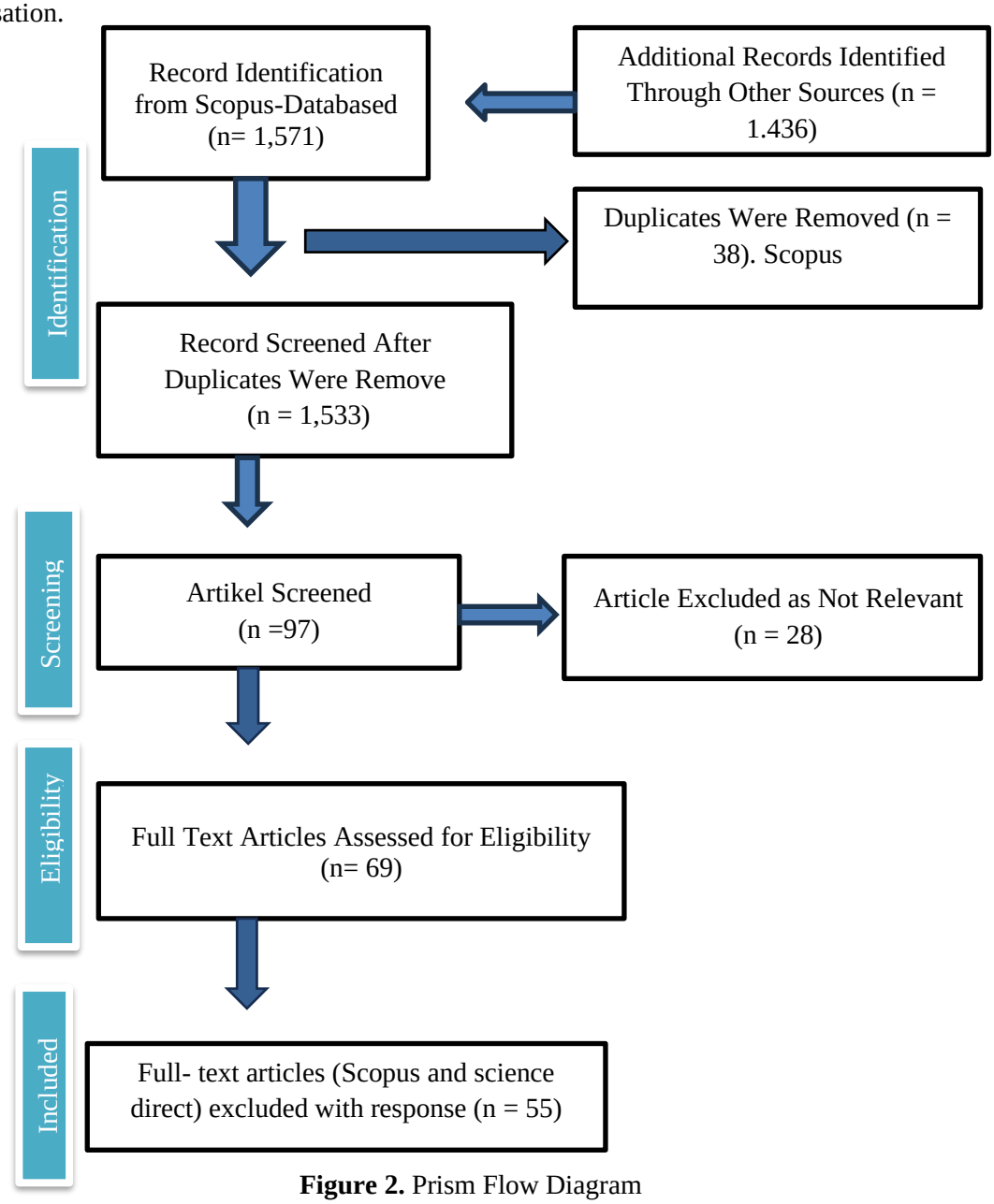

Figure 2. Prism Flow Diagram

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Figure 2 shows the stages of searching with the prism flow, which include identification, filtering, eligibility, and inclusion. A total of 1,571 articles were found in the Scopus database with the keyword problem-solving. Then, the articles were checked for similarity or duplicates. After that, 38 duplicates were removed. And, 1,533 Scopus-indexed articles had additional records found from other sources. However, 1,436 articles were not used because they were not appropriate. To ensure keyword suitability, article searches were conducted only in Scopus-indexed databases. Of the total 97 articles found, 28 irrelevant reports were excluded. As a result, 69 articles used, including 55 articles of review studies. These articles were then evaluated and analysed before being presented according to the research questions.

RESULT AND DISCUSSION

After the screening and assessment process is complete, the selected articles will be presented based on the type of research, methodology, and relevance. In the first stage, it discusses the concept of problem-solving in physics. Finally, the study identify and discuss the students' challenges and barriers in physics learning. This approach is expected to provide a comprehensive overview of the topic.

1. The concept of problem solving in Physics.

a. Definition and steps of problem solving in physics

Risma Anita defines problem-solving as an important skill for students during the learning process. This ability refers to the students ability to solve physics problems in an appropriate and effective way (Puriani & Dewi, 2020). Heller suggests several important steps in the problem-solving process. First, students need to be trained to focus on the problem, select relevant questions, make appropriate sketches, and determine appropriate approaches. Second, they need to relate the problem to the right physics concepts. Next, students need to be trained to think creatively in formulating a solution. Fourth, after understanding the plan, students must apply the solution correctly, including making observations, calculations, and answering questions accurately. Finally, students must evaluate the solution to ensure its effectiveness (Kenneth & Heller, 2010).

b. Purpose and role of problem-solving in physics learning

The problem-solving ability is one of the most important skills in facing various challenges, both in the academic and in everyday life (Ramadhani et al., 2021). In the world of education, it allows students to think critically, analyse situations, and find appropriate and effective solutions. Meanwhile, in the context of real life, this ability is very useful for making rational decisions, resolving conflicts, and navigating various complex situations that often do not have one definite answer. Therefore, mastery of problem-solving skills not only supports academic success but also equips individuals with essential life skills to adapt and thrive amidst the ever-changing dynamics of society. One of the main purposes and roles of problem-solving skills in students is to test hypotheses, solve complex problems, convey relevant formulas or equations, build arguments based on data and observations, and collaborate effectively in teams (Fitriyani et al., 2019). Therefore, the learning process must be carefully designed with an emphasis on developing these skills to encourage students to think critically and consciously in facing and solving various problems (Sagita et al., 2018).

c. Factors affecting the success of problem-solving

Saiye et al., (2024) shows three main factors in determining students' success in solving physics problems. First, it is directly related to the physics aspect itself, including poor students' ability to remember basic concepts and limited prior knowledge, difficulty in recognizing the core of the problem, poor of deep understanding of physics concepts, weak motivation to solve physics problems, and students' tendency to rely too much on their personal knowledge without considering broader approaches or systematic strategies.

The second aspect is cognitive factors. This aspect is assumed as one of the main causes of difficulties experienced by students in solving physics problems. Many students experience obstacles in applying physics concepts appropriately, such as difficulty in writing known or questionable information in the problem, and the tendency to use wrong or irrelevant formulas to the problem. In addition, students' analytical skills in understanding and working on problems, especially during exams, are still relatively poor, which hinders them in finding the right and appropriate solution.

Third, non-cognitive factors. It includes students' attitudes and personalities. Also, it affects their difficulties in understanding and solving physics problems. One of the main causes is the

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negative perception of physics as a difficult subject. This view makes students less focused, feel confused in completing the problems, and easily feel tired or sleepy during the learning process. In addition, learning methods dominated by lectures without active interaction make the material difficult to understand and reduce student's concentration. When the teacher gives practice problems that are different from the examples or previously explained, this may lead to confusion among students. In addition, the limited learning time and unsupportive learning facilities become obstacles, which make them to feel uncomfortable and have difficulty in understanding the material (Saiye et al., 2024).

d. Challenges in teaching and learning problem-solving

According to Hariyanto (2022), there are a number of challenges in the process of learning and teaching physics using problem-solving, for example, the habit of students who only study physics in the school. In home-work, they tend to complete them as best they can without repeating or reflecting on the previously learned material. Another difficulty arises when students are faced with physics problems, especially those in the form of narratives or containing concepts. Here, they might not able to relate the problem to relevant physics principles. This shows students' poor conceptual understanding and a poor of ability to think systematically in solving problems. Many students tend to focus only on the final answer without paying attention to the process or steps coherently (Hariyanto, 2022). These problems are largely caused by physics learning approaches that do not emphasize the development of problem-solving skills. As a result, students experience obstacles in understanding and solving problems that require deep thinking. In addition, teachers' teaching methods affect the effectiveness of learning. A lecture-centered approach often makes students passive and not actively involved in the learning process (Hariyanto, 2022).

e. Difficulties experienced by students in physics lessons.

At this time, there are many researchers from various countries who examine problems related to problem-solving or student difficulties in solving problems, especially in physics subjects. The following authors are present in the diagram of Figure 3:

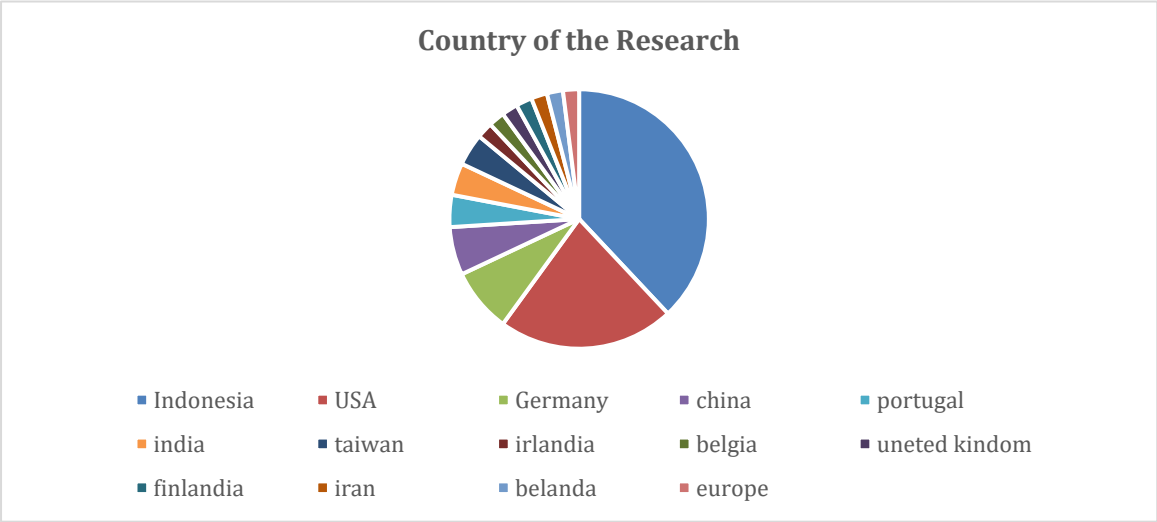

Figure 3. Research Country Diagram

Based on Figure 3, Indonesia is the most active country in conducting research related to problem-solving. Other countries also contributed to this research, including the United States, which produced eleven articles related to the topic raised by the author. Germany ranked second with four articles, followed by China with three articles. Portugal, India, and Taiwan had two articles. Meanwhile, Ireland, Belgium, the United Kingdom, Finland, Iran, and the Netherlands had one article each on problem solving in physics. By the high number of students who have difficulty in solving physics problems, it concluded that researchers from Indonesia are the most likely to conduct research in this field (Puspitaningtyas et al., 2021). Also, it is verified by Ryan that students have difficulties in understanding and mastering physics concepts. Moreover, there are challenges that need to be overcome in the physics learning process so that students can better understand the material taught (Ryan et al., 2018a).

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According to the analysis of several journals (Sutarja & Wulandari, 2021), many students in Indonesia consider arithmetic subjects, such as physics and maths, as scary and difficult to understand (Rohmah & Sutiarso, 2018) due to the way the lessons are delivered, which are not interesting and seem scary to students. As a result, many students feel bored and do not respond well (Sartika & Humairah, 2018). In addition, teachers often use monotonous learning models, which do not provide enough space for students to be creative in their learning process. This situation has an impact on the achievement of non-optimal learning outcomes for students (Dafik et al., 2023). As a result, as the learning process progresses, students do not understand the importance of the physics of mathematics.

Students need to improve their critical thinking skills. To achieve higher-order thinking skills, they must build skills by solving physics problems (Prastiti, 2020), One of the main reasons why students have difficulty on understanding physics lessons in the context of everyday life is the use of inappropriate learning models or methods by teachers, which has an impact on decreasing student interest and involvement. Physics problem-solving might be one of the effective approaches to help students develop these skills (Sartika & Humairah, 2018).

The similar thing was also conveyed by Sutama et al (Sutama et al., 2022). This study revealed that some of the factors cause students to face difficulties in solving physics problems are poor learning management. Teachers often only use conventional learning methods without any innovation or creativity, and often apply inappropriate methods (Manurung & Panggabean, 2020). In addition, variations in problem-solving approaches - during teaching and learning activities- are irregular, which has an impact on students' attitudes towards physics problem solving and affect their motivation to learn the all-important critical thinking skills. On the other hand, the number of teachers who truly understand the complexity of problem-solving and can adequately teach basic problem-solving skills is still very limited, which contributes to the failure in the learning process (Shabrina & Kuswanto, 2018).

In addition, students often assume that physics and maths are very difficult, scary, and boring subjects, which is largely due to their inability to understand the concepts. Students' difficulties in solving problems often arise due to teaching materials or learning approaches that are not in accordance with their abilities (Yayuk & Husamah, 2020). Another contributing factor is the poor of laboratory facilities and infrastructure for experimental practice, which can hinder students' ability to solve problems and cause them to feel bored and sleepy during learning. Moreover, the absence of specific development programmes for students in the subject is considered as a significant obstacle (Waruwu et al., 2023).

The results showed that many students had poor learning achievements in science materials, such as density and light reflection in mirrors. The caused factor is the teachers' lack of attention to students' science process skills, critical thinking ability, and a lack of focus on the material being taught (Pathoni et al., 2020). Furthermore, research has revealed that many students have low achievement in magnetic field materials in physics, which negatively impacts their understanding of important concepts (Prahani et al., 2022). Furthermore, students are underdeveloped in metacognitive skills and conceptual understanding of chemistry (Syahmani et al., 2020).

Furthermore, another article examines that students experience various difficulties in facing challenges in the subject matter of geometry and partial derivatives (Galitskaya & Drigas, 2023). In addition, factors, such as economic, health, mental, and technological issue also lead to the students' difficulties (Andrews Todd et al., 2023). It is important to note that mental state is the most crucial aspect in starting the learning process; without a strong mental state and spirit, the learning will not be effective, although students did not experience much difficulty with conceptual and procedural aspects. Instead, they had difficulties with chain rules and representational aspects in partial derivatives (Bajracharya et al., 2019). In line with the finding that students have three main difficulties in mathematics lessons that require skills, where the main difficulty is understanding the concept of limits, including the process of infinite limits, the formal definition of limits, and the value of limits (Díaz, 2022).

The students' difficulty in solving problems, particularly in the United States, is influenced by the context of students' knowledge elements. Student has a different level of preparation, both academic and general, which may affect learning outcomes and pose challenges in subjects that are difficult to measure with grades or evaluations (Stewart et al., 2021). In addition, changes in teaching

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methods and forms of teaching may help students who are less capable in the learning process (Burkholder et al., 2022). Students' difficulties mostly come from arithmetic or complex mathematics. However, these difficulties do not only arise from the math itself. But they are also influenced by the cyclical nature of the physics curriculum, where some physics topics are taught repeatedly in different contexts throughout the undergraduate curriculum (Wilcox & Corsiglia, 2019).

Factors that contribute to students' difficulties in problem solving, especially in physics lessons in Germany, include the importance of making adaptations before learning and predicting students' response behaviour to assess their ability to solve problems correctly. In addition, understanding students' motor skills during the learning process is important to reduce the boredom that students may experience during the lesson (Becker et al., 2022). By paying attention to these aspects, it might improve learning effectiveness and students' ability to solve physics problems (Loibl & Leukel, 2023).

Factors that cause students' difficulties in problem-solving can also be found in China. Although the country is highly developed, many students in physics classes face challenges in solving problems, for example, the learning model applied in innovative design courses (Tu et al., 2023). Several other factors, such as gender, management behaviour, learning style, learning motivation, individual characteristics, and students' interactions, can also affect students' ability in collaborative problem solving (CPS). Students' learning styles can have a significant impact on the CPS results (He et al., 2023).

In Portugal, factors influencing students' difficulties in problem solving include relatively low levels of entry preparation, which include students from underrepresented groups (URM), majority students, and first-generation and next-generation students (Silva, 2023). Research suggests that social psychological factors might not predict course performance in this population. Nonetheless, many studies indicate that students in the upper division still have difficulty in problem-solving problems, even in advanced physics courses. Such difficulties are mostly caused by complicated mathematical material and the difficult characteristics of physics. In addition, challenges at the upper secondary level can be triggered by the cyclicality of the physics course curriculum, where some topics are taught repeatedly in different contexts. If difficulties in these topics are not addressed, the problem will persist and, even worsen, teachers do not pay enough attention and move on to the next material (Ryan et al., 2018b). However, some schools showed a significant positive impact of skills-based labs compared to concept-based labs, which was seen in assessments for all student demographics. The reason is largely due to the increased use of activities that focus on students' decision-making and communication (Walsh et al., 2022).

Unlike the conditions in India, challenges in physics learning can be caused by various factors, such as individual or professional involvement, hypotheses proposed, media used, and research studies conducted. In the early stages of learning, students are expected to face a problem, an enquiry, or a challenge that they want to solve. This can be done by performing a practical exercise combined with theoretical discussions and the application of appropriate and interesting methods (Tanna et al., 2022).

Moreover, in countries such as Taiwan, Ireland, Belgium, the UK, Finland, Iran, the Netherlands, and in Europe, many students at the secondary school level find physics as a difficult subject due to the need to apply mathematical procedures in solving various physics problems. Therefore, it is crucial for teachers to understand the approaches that students use in physics and maths problem-solving (Pals et al., 2023).

Challenges in understanding linear functions in the context of maths and physics also found, especially in graph of x and y (Ceuppens et al., 2019). In addition, students face difficulties with vector material related to algebra, Newtonian dynamics, and magnetism (Karnam et al., 2020). There are differences in brain ability or activation, where some students may be slower or faster in understanding the material (Pereira et al., 2020). Therefore, interaction between teachers and students is necessary to ensure that students feel confident in learning physics. Moreover, teachers should apply appropriate learning approaches and models, as well as provide more opportunities for guided practicals with theoretical discussions (Garg et al., 2023).

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Based on the previous discussion, it concluded that students often experience confusion in performing critical analysis, evaluation, or synthesis to solve problems in their field of study, mainly due to a lack of academic support (Lin et al., 2023). In some countries, students' ability to solve physics problems largely depends on their efforts. However, in other countries, students' poor mathematical ability is a hinder factor in understanding physics. To help students, teachers should start by giving successful examples, followed by solving similar problems (Chen et al., 2020). In addition, it is important to reduce students' boredom by using computer-based learning methods (Chevalère et al., 2023).

The evidence suggests that students' interest in reading science is closely related to poor academic performance (Jian, 2022). One of the causes is poor preparation of students and excessive course load (Fischer et al., 2023). Students often feel that the physics curriculum is difficult to understand, and the learning models and methods used do not appropriate the way they learn, so they feels boring. In addition, physics materials are often considered not interesting with students' interests and talents. As a result, they feel forced to learn, lose their curiosity, and perceive physics as a very difficult subject that only contains numbers. These factors point to the need for a more innovative approach in teaching physics, which aims to increase students' interest and engagement

CONCLUSIONS

Based on the results of a systematic review of 50 journal articles that discuss problem-solving in physics learning, it concluded that problem-solving-based approaches have a significant positive impact on improving students' conceptual understanding, critical thinking skills, and analytical abilities. Most studies show that learning models that emphasize the exploration of contextual problems, the use of scientific thinking strategies, and collaborative integration, can increase student engagement and the effectiveness of physics learning. However, a number of barriers often arise in their implementation, such as low teacher readiness in applying problem-based methods, limited resources, and students' tendency to focus on the final answer rather than systematic thinking processes. Non-cognitive factors, such as negative perceptions of physics and low motivation to learn, are also obstacles that are often reported in various studies.

In general, the results of this SLR emphasize the importance of physics learning design that integrates the problem-solving approach in a consistent and structured manner. Training support for teachers, provision of contextual learning media, and development of evaluation strategies that assess students' thinking processes are recommended steps to optimize the effectiveness of physics learning through problem-solving

REFERENCE

Aisy, M. R., Trisnowati, E., & Siswanto, S. (2024). The Effect of the Problem-Based Learning (PBL) Model in the Context of Socio-Scientific Issues (SSI) on Critical Thinking Ability on Digestive System Material. *Jurnal Inovasi Pendidikan IPA*, *10*(2), 185–195. https://doi.org/10.21831/jipi.v10i2.75231

Andrews-Todd, J., Jiang, Y., Steinberg, J., Pugh, S. L., & D'Mello, S. K. (2023). Investigating collaborative problem solving skills and outcomes across computer-based tasks. *Computers and Education*, *207*. https://doi.org/10.1016/j.compedu.2023.104928

Aulia, J., Permana P, N. D., Zarkasih, Z., & Nova, T. L. (2020). Meta-Analisis Pengaruh Penerapan Pendekatan Saintifik Berbantuan Komik terhadap Hasil Belajar IPA Siswa SMP. *Journal of Natural Science and Integration*, *3*(1), 70. https://doi.org/10.24014/jnsi.v3i1.9617

Bajracharya, R. R., Emigh, P. J., & Manogue, C. A. (2019). Students' strategies for solving a multirepresentational partial derivative problem in thermodynamics. *Physical Review Physics Education Research*, *15*(2). https://doi.org/10.1103/PhysRevPhysEducRes.15.020124

Becker, S., Küchemann, S., Klein, P., Lichtenberger, A., & Kuhn, J. (2022). Gaze patterns enhance response prediction: More than correct or incorrect. *Physical Review Physics Education Research*, *18*(2). https://doi.org/10.1103/PhysRevPhysEducRes.18.020107

ISSN 2406-9205 (print), ISSN 2477-4820 (online)

Burkholder, E., Salehi, S., Sackeyfio, S., Mohamed-Hinds, N., & Wieman, C. (2022). Equitable approach to introductory calculus-based physics courses focused on problem solving. *Physical Review Physics Education Research*, *18*(2). https://doi.org/10.1103/PhysRevPhysEducRes.18.020124

Busnawir dan Asrul Sani. (2018). *Pengukuran kemampuan berpikir kreatif matematika tinjauanmelalui pembelajaran berbasis problem solving dan gaya belajar* (M. Sc. ,Ph. D. Prof. Asrul Sani, Ed.; buku). CV. Adanu Abimata.

Ceuppens, S., Bollen, L., Deprez, J., Dehaene, W., & De Cock, M. (2019). 9th grade students' understanding and strategies when solving x (t) problems in 1D kinematics and y (x) problems in mathematics. *Physical Review Physics Education Research*, *15*(1). https://doi.org/10.1103/PhysRevPhysEducRes.15.010101

Chen, O., Retnowati, E., & Kalyuga, S. (2020). Element interactivity as a factor influencing the effectiveness of worked example–problem solving and problem solving–worked example sequences. *British Journal of Educational Psychology*, *90*(S1), 210–223. https://doi.org/10.1111/bjep.12317

Chevalère, J., Lazarides, R., Yun, H. S., Henke, A., Lazarides, C., Pinkwart, N., & Hafner, V. V. (2023). Do instructional strategies considering activity emotions reduce students' boredom in a computerized open-ended learning environment? *Computers and Education*, *196*. https://doi.org/10.1016/j.compedu.2023.104741

Dafik, Kadir, Maryati, T. K., Sufirman, & Ridlo, Z. R. (2023). The analysis of the implementation of RBL-STEM learning materials in improving student's meta-literacy ability to solve wallpaper decoration problems using local antimagic graph coloring techniques. *Heliyon*, *9*(6). https://doi.org/10.1016/j.heliyon.2023.e17433

Díaz, V. (2022). Ability of engineering undergraduates to solve real function limit problems Capacidad de los estudiantes de ingeniería para resolver problemas de límite de funciones reales. In *Revista chilena de ingeniería* (Vol. 30, Issue 4). https://orcid.org/0000-0001-5483-3428

Fischer, K., Sullivan, A. M., Cohen, A. P., King, R. W., Cockrill, B. A., & Besche, H. C. (2023). Using cognitive load theory to evaluate and improve preparatory materials and study time for the flipped classroom. *BMC Medical Education*, *23*(1). https://doi.org/10.1186/s12909-023-04325-x

Fitriyani, R. V., Supeno, S., & Maryani, M. (2019). Pengaruh LKS Kolaboratif Pada Model Pembelajaran Berbasis Masalah Terhadap Keterampilan Pemecahan Masalah Fisika Siswa SMA. *Berkala Ilmiah Pendidikan Fisika*, *7*(2), 71. https://doi.org/10.20527/bipf.v7i2.6026

Galitskaya, V., & Drigas, A. S. (2023). Mobiles & ICT Based Interventions for Learning Difficulties in Geometry. *International Journal of Engineering Pedagogy*, *13*(4), 21–36. https://doi.org/10.3991/ijep.v13i4.36309

Garg, V., Deep, K., & Bansal, S. (2023). Improved Teaching Learning Algorithm with Laplacian operator for solving nonlinear engineering optimization problems. *Engineering Applications of Artificial Intelligence*, *124*. https://doi.org/10.1016/j.engappai.2023.106549

Hariyanto. (2022). Kesulitan Pemecahan Masalah Fisika pada Siswa MAN 3 Jember. *Assuniyah: Jurnal Ilmiah Mahasiswa*, *1*(2), 58–67.

He, S., Shi, X., Choi, T.-H., & Zhai, J. (2023). How do students'roles in collaborative learning affect collaborative problem-solving competency? A systematic review of research. *Thinking Skills and Creativity*, *50*, 101423. https://doi.org/10.1016/j.tsc.2023.101423

Irfan Taufari Asfar Syarif Nur. (2018). *Model Pembelajaran PPS (Problem Posing dan Solving).* (Hani Wijayanti, Ed.). CV Jejak .

Jian, Y. C. (2022). Influence of science text reading difficulty and hands-on manipulation on science learning: An eye-tracking study. *Journal of Research in Science Teaching*, *59*(3), 358–382. https://doi.org/10.1002/tea.21731

Karnam, D., Mashood, K. K., & Sule, A. (2020). Do student difficulties with vectors emerge partly from the limitations of static textbook media? *European Journal of Physics*, *41*(3). https://doi.org/10.1088/1361-6404/ab782e

ISSN 2406-9205 (print), ISSN 2477-4820 (online)

Kenneth Heller and Patricia Heller. (2010). *Cooperative Problem Solving in Physics A User's Manual* (Department of Education, Ed.). National Science Foundation, University of Minnesota, and U.S.

Lin, M., Liu, L. Y. J., & Pham, T. N. (2023). Towards developing a critical learning skills framework for master's students: Evidence from a UK university. *Thinking Skills and Creativity*, *48*. https://doi.org/10.1016/j.tsc.2023.101267

Loibl, K., & Leukel, C. (2023). Problem-solving prior to instruction in learning motor skills - Initial self-determined practice improves javelin throwing performance. *Learning and Instruction*, *88*. https://doi.org/10.1016/j.learninstruc.2023.101828

Manurung, S. R., & Panggabean, D. D. (2020). Improving students' thinking ability in physics using interactive multimedia based problem solving. *Cakrawala Pendidikan*, *39*(2), 460–470. https://doi.org/10.21831/cp.v39i2.28205

Pals, F. F. B., Tolboom, J. L. J., & Suhre, C. J. M. (2023). Development of a formative assessment instrument to determine students' need for corrective actions in physics: Identifying students' functional level of understanding. *Thinking Skills and Creativity*, *50*. https://doi.org/10.1016/j.tsc.2023.101387

Pathoni, H., Kurniawan, W., Muliawati, L., Kurniawan, D. A., Dari, R. W., Ningsi, A. P., & Romadona, D. D. (2020). The effect of science process skills on study critical thinking ability in scientific learning. *Universal Journal of Educational Research*, *8*(11), 5648–5659. https://doi.org/10.13189/ujer.2020.081169

Pereira, T., Castro, M. A., Villafaina, S., Santos, A. C., & Fuentes-García, J. P. (2020). Dynamics of the prefrontal cortex during chessbased problem-solving tasks in competition-experienced chess players: An fnir study. *Sensors (Switzerland)*, *20*(14), 1–12. https://doi.org/10.3390/s20143917

Prahani, B. K., Rizki, I. A., Nisa, K., 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), 379–396. https://doi.org/10.3926/jotse.1590

Prastiti, T. D. (2020). Problem-based learning on the learning perseverance of indonesian senior high school students in solving mathematical problems. *Bolema - Mathematics Education Bulletin*, *64*(68), 1206–1220. https://doi.org/10.1590/1980-4415v34n68a17

Puspitaningtyas, E., Putri, E. F. N., Umrotul, & Sutopo. (2021). Analysis of high school students' mastery in light wave theory using structured inquiry learning assisted by a virtual laboratory. *Revista Mexicana de Fisica E*, *18*(1), 10–22. https://doi.org/10.31349/REVMEXFISE.18.10

Ramadhani, F. D., Wati, M., Misbah, & Wiyono, K. (2021). The Validity of Electronic Learning Materials Optical Instruments Based on Authentic Learning to Train Students' Problem Solving Skills. *Kasuari: Physics Education Journal (KPEJ)*, *4*(2), 78–89.

Risma Anita puriani dan ratna Sari Dewi. (2020). *Konsep Adversity dan Problem Solving Skill* (Armitha Mukhromah dan Nur Sharfina aprilliani, Ed.; book). Bening Media Publishing.

Rizal, R., Shandy, V. R., Rusdi, M. S., & Afriyeni, H. (2024). Kajian Kepuasan Pasien Terhadap Pelayanan Kefarmasian Di Apotek Rawat Jalan RSUD Sungai Dareh. *Jurnal Penelitian Dan Pengkajian Ilmiah Eksakta*, *3*(2), 58–67. https://doi.org/10.47233/jppie.v3i2.1518

Rohmah, M., & Sutiarso, S. (2018). Analysis problem solving in mathematical using theory Newman. *Eurasia Journal of Mathematics, Science and Technology Education*, *14*(2), 671–681. https://doi.org/10.12973/ejmste/80630

Ryan, Q. X., Wilcox, B. R., & Pollock, S. J. (2018a). Student difficulties with boundary conditions in the context of electromagnetic waves. *Physical Review Physics Education Research*, *14*(2), 020126. https://doi.org/10.1103/PhysRevPhysEducRes.14.020126

Sadiqin, I. K., Santoso, U. T., & Sholahuddin, A. (2017). Pemahaman konsep IPA siswa SMP melalui pembelajaran problem solving pada topik perubahan benda-benda di sekitar kita. *Jurnal Inovasi Pendidikan IPA*, *3*(1), 52. https://doi.org/10.21831/jipi.v3i1.12554

ISSN 2406-9205 (print), ISSN 2477-4820 (online)

Sagita, I., Medriati, R., & Purwanto, A. (2018). Penerapan Creative Problem Solving Model untuk Meningkatkan Kemampuan Pemecahan Masalah Fisika Siswa Kelas XI MIA 4 MAN 2 Kota Bengkulu. *Jurnal Kumparan Fisika*, *1*(3), 1–6.

Saiye, N., Amin, B. D., & Subaer. (2024). Analisis Kesulitan Peserta Didik Dalam Memecahkan Masalah Fisika Pada Siswa Kelas Xi Sma Negeri 2 Makassar. *Jurnal Sains Dan Pendidikan Fisika*, *20*(3), 301–312. https://doi.org/10.35580/jspf.v20i3.5305

Sartika, D., & Humairah, N. A. (2018). Analyzing Students' Problem Solving Difficulties on Modern Physics. *Journal of Physics: Conference Series*, *1028*(1). https://doi.org/10.1088/1742-6596/1028/1/012205

Shabrina, & Kuswanto, H. (2018). Android-assisted mobile physics learning through indonesian batik culture: Improving students' creative thinking and problem solving. *International Journal of Instruction*, *11*(4), 287–302. https://doi.org/10.12973/iji.2018.11419a

Silva, M. J. (2023). A didactic model to support the use of senses and sensors in environmental education problem solving. *Australian Journal of Environmental Education*, *39*(1), 108–124. https://doi.org/10.1017/aee.2022.22

Sri Purwanti dan Sondang Manurung. (2015). Analisis Pengaruh Model Pembelajaran Problem Solving dan Sikap Ilmiah Terhadap Hasil Belajar Fisika. *Jurnal Pendidikan Fisika*, *Vol. 4 No. 1*, 58–58.

Stewart, J., Cochran, G. L., Henderson, R., Zabriskie, C., Devore, S., Miller, P., Stewart, G., & Michaluk, L. (2021). Mediational effect of prior preparation on performance differences of students underrepresented in physics. *Physical Review Physics Education Research*, *17*(1). https://doi.org/10.1103/PhysRevPhysEducRes.17.010107

Sutama, S., Fuadi, D., Narimo, S., Hafida, S. H. N., Novitasari, M., Anif, S., Prayitno, H. J., Sunanih, S., & Adnan, M. (2022). Collaborative mathematics learning management: Critical thinking skills in problem solving. *International Journal of Evaluation and Research in Education*, *11*(3), 1015–1027. https://doi.org/10.11591/ijere.v11i3.22193

Sutarja, M. C., & Wulandari, A. Y. R. (2021). Identifying students' difficulty in the basic of thermodynamics. *Journal of Physics: Conference Series*, *2126*(1). https://doi.org/10.1088/1742-6596/2126/1/012010

Syahmani, Suyono, & Imam Supardi, Z. A. (2020). Effectiveness of i-smart learning model using chemistry problems solving in senior high school to improve metacognitive skills and students' conceptual understanding. *Pedagogika*, *138*(2), 37–60. https://doi.org/10.15823/p.2020.138.3

Tanna, P., Lathigara, A., & Bhatt, N. (2022). Implementation of Problem Based Learning to Solve Real Life Problems. In *Journal of Engineering Education Transformations* (Vol. 35).

Tu, J. C., Lo, T. Y., & Zhang, X. Y. (2023). Applying the ATDE-based model of teaching creativity to improvement of students' learning in a design practice course. *Thinking Skills and Creativity*, *48*. https://doi.org/10.1016/j.tsc.2023.101293

Walsh, C., Lewandowski, H. J., & Holmes, N. G. (2022). Skills-focused lab instruction improves critical thinking skills and experimentation views for all students. *Physical Review Physics Education Research*, *18*(1). https://doi.org/10.1103/PhysRevPhysEducRes.18.010128

Waruwu, M., Dwikurnaningsih, Y., & Satyawati, S. T. (2023). Online-based activities to improve students' critical thinking, problem solving, and communication. *International Journal of Evaluation and Research in Education*, *12*(3), 1645–1653. https://doi.org/10.11591/ijere.v12i3.24719

Wilcox, B. R., & Corsiglia, G. (2019). Cross-context look at upper-division student difficulties with integration. *Physical Review Physics Education Research*, *15*(2). https://doi.org/10.1103/PhysRevPhysEducRes.15.020136

Yayuk, E., & Husamah, H. (2020). The difficulties of prospective elementary school teachers in item problem solving for mathematics: Polya's steps. *Journal for the Education of Gifted Young Scientists*, *8*(1), 361–378. https://doi.org/10.17478/jegys.665833

ISSN 2406-9205 (print), ISSN 2477-4820 (online)