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Development of Physics Teaching Material with Problem-Based Learning to Train Students' Problem-Solving Skills

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Abstract

In the era of Industry 4.0, problem-solving skills are crucial to address life's increasingly complex and diverse challenges. However, these skills are often not adequately cultivated in schools. This study aims to describe the suitability of physics teaching materials using problem-based learning (PBL) to enhance students' problem-solving skills in the topic of light and optical instruments. This research employs the Dick and Carey development model, involving five validators, ten students in a limited test, and 15 students in an extensive trial. Data is collected using validation instruments, observation of learning, and problem-solving tests. The results of the study indicate that the validation results of physics teaching materials, including lesson plans, teaching materials, student worksheets, and problem-solving tests, are 93, 92, 90, and 92, respectively, with a "very valid" rating. Furthermore, PBL activities in the limited and extensive trials are 84 and 86, respectively, with a "practical" categorization. In conclusion, the physics teaching materials developed using PBL are suitable for training problem-solving skills in physics education. These materials can be applied in secondary school-level education, particularly for light and optical instruments, to enhance students' problem-solving abilities.

Keywords: Light and optical instruments, Problem-solving skills, Problem-based learning

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INTRODUCTION

Knowledge is a fundamental human need because people are born without prior knowledge. Therefore, humans naturally learn about everything around them (Indriani & Lazulva, 2020). The science subject teaches systematic knowledge about the natural world, how nature and all its components work, and the creation of new discoveries based on applied knowledge about nature (Kastriti et al., 2022; Sulikah et al., 2020). Through science education, students can learn about their surroundings and use it to understand themselves and the world around them. It also helps train students to think and apply this knowledge daily (Wulandari & Mudinillah, 2022).

Science education aims to develop students' competencies so that they can understand the natural world through scientific methods, focusing on direct learning experiences (Putra, 2021). One of the expected skills to emerge as students engage in science activities is the development of higher-order thinking skills, including problem-solving skills (Ariani, 2020). Students are encouraged to connect their daily life problems with the subject matter they have learned in school (Alam, 2022; Inganah et al., 2023). High-order thinking methods go beyond mere memorization and help students better understand concrete science. Students learn to understand problems, create plans to solve them, implement them, and evaluate the plan results (Prasetyo et al., 2019).

School science education is often delivered conventionally, with students tending to memorize concepts. Teachers often use conventional teaching methods, leading students to find physics classes boring (Wahyuni, 2021). This results in students not being trained to think critically. However, these skills need to be developed early so students can solve problems effectively (Azid et al., 2022; Zain et al., 2022). According to Bloom's taxonomy, higher-order thinking skills fall within the C4-C6 range.

This research began with data collection through surveys using purposive sampling, which was given to teachers in various districts in South Kalimantan. Out of 32 survey responses, it was found that 96.9% of students experienced difficulties when answering questions involving High Order Thinking Skills (HOTS) or questions at the C4 level and above. The follow-up question regarding the factors causing these problems yielded the top three answers: (1) Students are not used to answering HOTS questions (78.1%), (2) Students are not skilled in problem-solving (59.4%), (3) students have low mathematical skills (53.1%). Furthermore, 93.8% of students stated that there were also teacher-related factors affecting this issue, including (1) teachers struggling to teach HOTS-based material (65.6%) and (2) teachers lacking HOTS-oriented teaching materials (50%). The consequences for students if they are not trained in solving HOTS questions include: (1) students will find it difficult to solve everyday problems (62.5%), (2) students may not be creative thinkers (56.3%), and (3) students may have difficulty analyzing problems that arise (56.3%).

The study by Rakhmi et al. (2020) indicates difficulties in learning science, including a low understanding of concepts, misconceptions, and the ability to connect learning to everyday occurrences. Other research suggests that the potential causes of students' problems in solving problems include their lack of attention during problem-solving, low mathematical skills, suboptimal learning activities, a weak understanding of questions, incomplete reading of questions, lack of motivation, and interest (Gais et al., 2017; Hadiyanti et al., 2022; Heri et al., 2022).

Another study by Yatul & Fitri (2022) stated that students need teaching materials to facilitate problem-solving skills. These materials should include everyday content, example problems with step-by-step procedural solutions, and supporting media like simulations to engage students. Additionally, these materials should include a collection of formulas and group exercises for practice.

Several other relevant studies have been conducted to develop problem-solving skills. Tampubolon et al. (2021) developed effective PBL teaching materials to train high school students in problem-solving skills. Applying PBL teaching materials can improve students' mathematical problem-solving and metacognition abilities (Siagian et al., 2019). Developing teaching materials by Liiman et al. (2022) in Contextual Teaching and Learning enhances problem-solving abilities. The problem-solving indicators in these three studies refer to the stages of problem-solving according to Polya, which are understanding the problem, creating a plan for the solution, implementing the plan, and reviewing the solution (Polya, 1973).

Based on the above description, this paper aims to describe the suitability of teaching materials developed through problem-based learning in training students' problem-solving abilities. Initial data was obtained through interviews with teachers as respondents regarding the question of what teaching materials should be developed, including (1) teaching materials (93.8%), (2) lesson plans (84.4%), (3) student worksheets (78.1%), and problem-solving tests (78.1%). Additionally, 93.8% of respondents desired implementing problem-based learning in designing physics teaching materials. PBL is a learning model that encourages active learning, develops learning experiences, and enhances problem-solving skills and metacognition (Surya et al., 2017; Sutarto et al., 2022). PBL can be used to sharpen students' higher-order thinking and problem-solving skills (Surya & Syahputra, 2017). Therefore, there is a need to develop practical physics teaching materials with PBL that can be adapted for physics learning to address these weaknesses.

Physics content taught is undoubtedly related to everyday problems in the students' environment. In this context, choosing light and optical instruments as the topic is considered suitable to help students practice and develop problem-solving skills. The topic of light includes properties of light, such as reflection and refraction, which are highly relevant to everyday occurrences. A research study conducted by (Rizaldi et al., 2022) suggested that learning difficulties in the properties of light and optical instruments are due to the lack of suitable learning materials. Therefore, it is essential to develop physics teaching materials for this topic to be used in learning.

Fidan & Tuncel (2019) explained that PBL can be integrated with various modern technologies. This topic can also be practiced virtually through tools like PhET. Rizal et al. (2021) described how PBL can use mobile phones as a medium for information gathering and investigative activities. The topic of optical instruments is also related to eye problems, allowing students to learn how to maintain healthy eyes and avoid potential eye problems. The learning outcomes are expected to benefit and have practical meaning for students directly. This research aims to create valid and practical PBL-based physics teaching materials to enhance students' problem-solving abilities.

METHOD

This study is a research and development using the Dick & Carey model to produce physics teaching materials by applying Problem-Based Learning (PBL) that are suitable for training problem-solving skills (Tampubolon et al., 2021). The developed teaching materials include lesson plans (*Rencana Pelaksanaan Pembelajaran*/ RPP), instructional materials, student worksheets (*Lembar Kerja Peserta Didik/* LKPD), and problem-solving tests. The design of the teaching materials followed Polya's four-stage problem-solving process.

The results of developing physics teaching materials were validated by three science education experts and two practitioners who are senior teachers. Based on the suggestions and feedback from the validators, improvements would be made, and the materials would be used in a limited and extensive trial. During the three meetings of the learning process, two observers would assess learning activities using a learning implementation instrument.

Subsequently, the validation and learning observation results were analyzed using Microsoft Excel to determine validation and practicality scores. The total score obtained would be divided by the maximum score and multiplied by 100. The resulting value would be adjusted according to the criteria, as shown in Table 1.

Table 1 Validation & practicality criteria

Score Assessment	Criteria
0 ≤ X < 50	Not valid/practical
50 ≤ X < 70	Less valid/practical
70 ≤ X < 85	Valid/ practical
85 ≤ X < 100	Very valid/ practical

(Suyidno et al., 2022)

RESULTS AND DISCUSSION

Teaching materials play a crucial role in the physics learning process as they can facilitate both teachers and students in their activities to achieve learning goals. Before use, teaching materials need to be validated to ensure their content and construct validity. The results of validating physics teaching materials with PBL can be seen in Tables 2 to 5.

Table 2 Lesson plan validation results

Assessment Aspect	Score	Criteria
Completeness of RPP components	95	Very valid
Completeness of activities for preparing students to learn	80	Valid
Clarity and logical formulation of learning objectives	95	Very valid
Completeness of learning objective formulations	85	Very valid
Integration of problem-solving skills in RPP	100	Very valid
Completeness of introductory, core, and closing activities	100	Very valid
Consistency of steps with learning objectives and time allocation	80	Valid
Activities for training problem-solving skills	100	Very valid
Consistency of teaching steps between teachers and students	100	Very valid
Student-centered	80	Valid
Utilization of learning resources in the environment	95	Very valid
Inclusion of assessment instruments	100	Very valid
Average	**93**	Very **valid**

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Table 2 shows that the assessment results of the lesson plans validation by the five validators fall into the "very valid" category with an average score of 93. Some improvement suggestions from the validators include enhancing motivation with images, clarifying the perception and the questions, remembering the ABCD pattern in learning objectives, and revisiting the closing section's process standards. Table 2 shows that the assessment results of the lesson plans validation by the five validators fall into the "very valid" category with an average score of 93. Some improvement suggestions from the validators include enhancing motivation with images, clarifying the perception and the questions asked, remembering the ABCD pattern in learning objectives, and revisiting the closing section's process standards. Wati (2021) suggests that when developing RPP, it should be written in language that is easy to understand and straightforward, with an attractive design that does not lead to misinterpretation. The results of teaching material validation are depicted in Table 3.

Table 3 The results of teaching material validation

Assessment Aspect	Score	Criteria
Relevant to the competencies students must master	100	Very valid
Depth appropriate to the student's level	95	Very valid
Presented by scientific accuracy	100	Very valid
Presented in line with the latest developments	80	Valid
Presented in alignment with everyday life	100	Very valid
Encourages students' curiosity for reading	90	Very valid
Facilitates interaction between learning resources and students	95	Very valid
Enables students to build their knowledge	90	Very valid
Systematic sequence according to RPP guidelines	95	Very valid
Appropriate sentence structure according to students' comprehension	95	Very valid
paragraph construction matching students' comprehension level	85	Very valid
Use of relevant images with explanations/descriptions	95	Very valid
Presentation of images with descriptions	100	Very valid
Accuracy in spelling following EYD standards	80	Valid
Accuracy in sentence structure adhering to EYD standards	85	Very valid
Average	**92**	**Very valid**

Table 3 presents the validation results for instructional materials. All 15 assessment aspects are highly rated, with 13 considered "very valid" and two aspects falling into the "valid" category. Validator suggestions include improving the cover, making it more appealing, using clear and appropriately sized images and fonts, and adding information about the latest optical instruments. Fatmawati et al. (2023) and Suttrisno & Puspitasari (2021) stated that the importance of an attractive design aims to capture the students' interest. The results of teaching material development is seen in Figure 1.

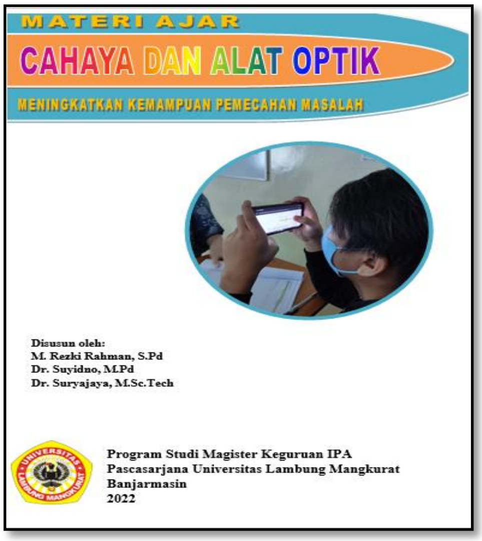

Figure 1 Cover of the teaching material

Regarding the development of teaching materials, the cover design has been improved based on suggestions and validation results from experts. The cover features an image of a student using PhET as a learning medium.

Figure 2 Science literacy corner

Figure 2 shows the science literacy corner, which functions to help students connect the materials to what they experience in daily life.

Contoh Soal 4. Miopi

Bagus menderita gangguan mata kesulitan melihat jauh, dia hanya bisa jelas melihat pada jarak 40 cm. Berapakah kuat lensa dan jenis lensa kacamata yang dapat digunakan bagus untuk dapat melihat secara jelas?

Penyelesaian:

1. Orientasi Masalah

Diketahui: PR = 40 cm = 0,4 m

Ditanyakan: Kekuatan lensa dan jenis lensa ?

2. Rencana Penyelesaian

Langkah 1: Menemukan P melalui persamaan 4.1

Langkah 2: Menemukan Jenis lensa yang tepat

3. Melaksanakan Rencana Penyelesaian

Langkah 1:

$$P = -\frac{1}{PR} = -\frac{1}{0.4} = -2.5\,D$$

Langkah 2:

Jenis gangguan penglihatan yang di derita bagus ialah kesulitan melihat jauh (miopi) lensa yang cocok digunakan ialah lensa cekung.

4. Melihat kembali hasil Penyelesaian

Jadi, kacamata yang harus digunakan oleh Bagus ialah kacamata dengan kuat lensa -2.5 D dan berupa lensa cekung.

Figure 3 Sample questions integrated with Polya's problem-solving

Figure 3 displays sample questions integrated with Polya's problem-solving steps. The intention is for students to become more accustomed to solving problem-based questions and the associated problem-solving steps through this teaching material. The results of students' worksheet validation are given in Table 4.

Table 4 Results of students' worksheet validation

Assessment Aspect	Score	Criteria
The LKPD (Learning Activity Sheet) emphasizes the problem-solving process	95	Very valid
The accuracy of cases presented with the material being taught	90	Very valid
Systematic training of problem-solving skills	95	Very valid
The use of interesting and supportive visuals in presented cases	95	Very valid
An attractive design that piques the interest of learners to read the LKPD.	75	Valid
Average	90	**Very valid**

According to Table 4, the validation results for the five aspects of LKPD show that four are in the "very valid" category, and one is in the "valid" category. Input and suggestions from the validator include simplifying the format and presentation of the LKPD, for instance, making data observation tables clearer. Students may not understand some terms related to variables. Add relevant images to the LKPD that align with the learning objectives, and use more detailed explanations to describe the steps in the LKPD to prevent errors during practical work. It is important to determine an attractive design to enhance the interest of learners in the learning process (Fatmawati *et al.*, 2023; Lestari & Muchlis, 2021). The results of the developed LKPD product can be observed in Figure 4 and Figure 5.

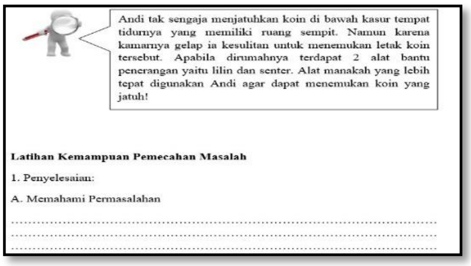

Figure 4 LKPD design before revision

Figure 4 shows that the design image still appears simple, the image is less relevant, and the text color used is only black. Conversely, in the image on the right, the design of the LKPD is starting to pay attention to layout, attractive images, and diverse text colors. These results can be compared with the improvements made after the revision in Figure 5.

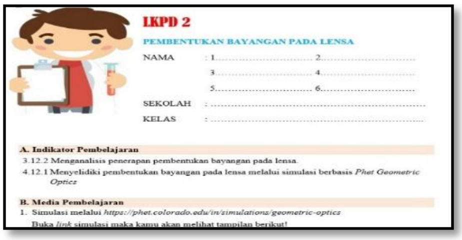

Figure 5 LKPD design after revision

Besides the design aspect, other aspects, such as the systematic sequence for training problem-solving skills and the accuracy of cases presented with the currently taught material, have received very positive assessments. Therefore, the LKPD created can be used in learning to develop problem-solving skills. The results of the problem-solving test (TPM) validation are presented in Table 5.

Table 5 Results of TPM validation

Assessment Aspect	Score	Criteria
Alignment of the assessment with the problem-solving skills	90	Very valid
Relevance of the questions to the taught material	100	Very valid
Clear scoring guidelines for measuring problem-solving skills	100	Very valid
Suitability of the time limit for completing the given questions	100	Very valid
Attractiveness of the design, capturing the participants' attention	80	Valid
Average	**94**	**Very valid**

Table 5 shows that the validation results of the evaluation sheet in these five aspects resulted in 4 aspects categorized as "very valid" and one aspect categorized as "valid." Overall, the validation results for learning outcomes have an average score of 92, which falls into the "very valid" category. Recommendations from the validator include using authentic problems rather than conceptual ones, aligning the questions with the learning objectives, and providing clear score breakdowns for each question, especially for qualitative questions. Case-based questions can enhance higher-level thinking skills in learners through investigation, problem-solving, presenting problem-solving results, and reviewing those results (Dwita & Hidayati, 2022; Andini et al., 2017).

The practicality assessment results for limited and broad tests can be observed in Tables 6 and 7, respectively. In Table 6, it can be seen that the practicality scores for Material 1 tend to be similar. Students are not yet accustomed to using the PBM model, so some activities take longer than planned. However, there is an improvement in the results for the subsequent material.

The orientation of a problem to students is the core of the first phase of PBM, which is the problem orientation phase. Khan et al. (2022) state that a question can become a problem if it challenges students in a way that cannot be solved with common methods. Therefore, the teacher should carry out problem orientation successfully for students effectively. In the second phase of PBM, the teacher's role is to facilitate students in defining the problem and organizing learning tasks.

In the following phase, guiding the investigation activities, the teacher encourages students to gather information to solve problems or conduct experiments to obtain explanations to solve problems. Fitriani et al. (2020) stated that problem-solving skills can be nurtured by providing meaningful learning, and the information-gathering activity helps students find solutions based on their research findings and thought processes, ultimately leading to answers to the problem.

It can be combined with supporting media such as the PhET Geometric Optics during this phase. Juwairiah et al. (2022) stated that PhET media has advantages, including students enjoying practical activities using this media, making experiments safer for students, and helping visualize concepts in an experiment. Research by Simanjuntak et al. (2021) indicates that using simulation media can improve learning success and provide facilities for students to be more active and easier in learning science concepts.

In Phase 4, students are asked to present the results of their discussions in front of the class. Zahro & Irawan (2022) stated that during the presentation activity, the teacher randomly selects students to present the results of their discussions with their groups. Students are asked to communicate in their own words, which they have written in the previous activity.

Table 6 Implementation results of the PBM phases in the limited test

Phase	Material 1		Material 3	
	Value	Criteria	Value	Criteria
Problem Orientation for Students	88	Very Practical	96	Very Practical
Organizing Students for Research	78	Practical	88	Very Practical
Guiding Individual and Group Research	78	Practical	84	Practical
Developing and Presenting Results	75	Practical	83	Practical
Problem-Solving Analysis and Evaluation	81	Practical	91	Very Practical
Average	**80**	**Practical**	**88**	**Very Practical**

Table 7 Implementation results of the PBM phases in the large-scale test

Phase	Material 1		Material 2		Material 3	
	Value	Criteria	Value	Criteria	Value	Criteria
Problem Orientation for Students	88	Very Practical	88	Very Practical	98	Very Practical
Organizing Students for Research	78	Practical	83	Practical	93	Very Practical
Guiding Individual and Group Research	80	Practical	83	Practical	91	Very Practical
Developing and Presenting Results	75	Practical	83	Practical	83	Practical
Problem-Solving Analysis and Evaluation	88	Very Practical	88	Very Practical	94	Very Practical
Average	**81**	**Practical**	**85**	**Practical**	**92**	**Very Practical**

In the presentation activity, the teacher can pose one or two questions to the presenter to assess the student's skills. Presentation activities are beneficial for the teacher to evaluate the student's ability to understand information, and the students can also practice their communication skills in public speaking. During the analysis and evaluation phase of the problem-solving process, the teacher can provide feedback based on the students' work. In Material 1, students used their mobile phones to conduct experiments using the PhET Geometric Optics app. Utilizing this media provides a direct insight into image formation through special rays. Students can better understand the image formation process through simulation activities using the media to explain the procedure more accurately during the presentation. Learning through PhET or virtual simulations can enhance learning outcomes and positively impact education (Laksono et al., 2023).

However, there are still challenges, including not all students having mobile phones with sufficient specifications to run the application, so they must use a phone from one of their group members. Additionally, in the evaluation process of the LKPD, some students have not completed it but submitted it due to time constraints.

Another issue is that students are not yet accustomed to PBM activities, so the teacher must provide instructions several times before they can start their activities. However, with each meeting, the learning activities have improved in line with the increasing feasibility scores in the limited and broad tests. Overall, despite challenges during the learning process and various obstacles, the assessment of the RPP implementation has been in accordance with the stages of PBM. Therefore, based on the results obtained from the limited test, it is categorized as very practical, and the broad test is also categorized as very practical. Based on these results, the physics teaching material developed using the PBM model is considered valid and practical and can be deemed suitable for classroom physics education.

CONCLUSION

Based on the research findings, it can be concluded that the teaching material for physics with PBM is suitable for use in learning, especially for enhancing students' problem-solving skills. This conclusion is based on the validation results of teaching materials, including RPP, teaching materials, LKPD, and problem-solving tests, which have met the criteria for validity. Furthermore, PBL activities can be implemented in limited, extensive trials with a practical category. Further research is needed to assess the effectiveness of the teaching material in improving students' problem-solving skills.

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