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Profile of the Problem-Based Learning Model Assisted by E-THERM to Strengthen Students' Problem-Solving Skills in Support of SDG 4: Quality Education

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ABSTRACT

Objective: *The purpose of this study is to analyze the problem-solving abilities of 11th-grade students at State Senior High School 1 Sidoarjo on the topic of temperature and heat as a foundation for implementing a digital book-assisted Problem-Based Learning (PBL) model.* ***Method:*** *This study employed a descriptive quantitative approach in the form of preliminary research involving 105 students selected through purposive sampling. Data were collected using essay tests based on Heller's five problem-solving indicators, a Likert-scale questionnaire, and teacher interviews, and were analyzed descriptively to examine students' initial abilities and readiness for digital book-assisted PBL implementation.* ***Results:*** *The findings show that 62.9% of students were categorized as having fair problem-solving abilities, 32.4% were in the poor category, and no students reached the good or very good categories. The physics description indicator was the most mastered aspect, while students' abilities declined starting from the plan-a-solution indicator, indicating difficulties in systematically applying physics concepts to problem-solving.* ***Novelty:*** *This study provides empirical evidence on students' readiness for implementing a digital book-assisted PBL model in physics learning, highlighting specific weaknesses in problem-solving indicators that can be addressed through the integration of digital learning resources within the PBL framework.*

INTRODUCTION

Advancements in science and technology in the 21st century require improvements in the quality of education, especially in scientific fields that play a crucial role in developing students' critical, analytical, and creative thinking skills (Lolanessa et al., 2020). This aligns with the Sustainable Development Goals (SDGs) point 4 on Quality Education, which emphasizes the importance of high-quality education to support higher-order thinking skills as essential competencies for addressing global challenges in the 21st century (Nations, 2020). One of the essential skills that students must possess is problem-solving ability. Problem solving is the final stage of higher-order thinking processes that connects critical and creative thinking skills to produce appropriate solutions (Yuliantaningrum & Sunarti, 2020). Problem-solving skills are closely related to students' ability to analyze situations, plan strategies, and evaluate solutions systematically, which can be effectively developed through student-centered learning approaches such as Problem-Based Learning (PBL). In this regard, the value of problem-solving skills is twofold: it is an indicator of the student's level of understanding of the concepts, and it also reflects the quality of the teaching strategies employed to promote substantial learning. Previous studies have consistently reported that PBL has a positive impact on students' problem-solving skills, critical thinking, and

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conceptual understanding in physics learning (Bagheri, 2021; Çalişkan et al., 2010; Jordan & McDaniel, 2023; Mahmud & Halim, 2021).

In physics learning at the secondary level, students' problem-solving ability is crucial for helping them understand abstract concepts and apply them to real-world phenomena. Heller et al. (1992) states that problem-solving skills consist of five indicators: visualize the problem, physics description, plan a solution, execute the plan, and check and evaluate. However, various studies indicate that students' ability to solve physics problems is still relatively low. Several studies have reported that students still experience difficulties and misconceptions in physics, particularly in applying concepts to problem-solving contexts. These difficulties are often related to weak conceptual understanding, low confidence, and limited experience with structured problem-solving strategies (Aydogdu, 2021; Husnulsyaidah et al., 2022; Suparno, 2020; Wijayanti & Kustijono, 2020). Students often struggle to understand and differentiate basic concepts such as temperature and heat, as well as to connect theoretical knowledge with contextual situations (Yuliana et al., 2020).

The topic of temperature and heat is an important concept because it is directly related to everyday phenomena. Nevertheless, research shows a high level of misconceptions in this area. Yuliana et al. (2020) found that only around 54.8% of students demonstrated good understanding of temperature and heat concepts, while many struggled to understand the factors that influence temperature changes, heat transfer processes, and changes in the state of matter.

Despite the importance of these indicators, a plethora of research suggests that the problem-solving abilities of students continue to be quite low. This is especially true in physics topics requiring a higher degree of abstract reasoning like heat and temperature. Many scholars (Suparno, 2020; Wijayanti & Kustijono, 2020) have noted that students tend to have the ability to recite pertinent formulas but still experience misconceptions and difficulties applying the concepts to problem situations. Most notably among studies on temperature and heat, students exhibited a lack of understanding related to heat transfer and phase changes, which signifies a struggle to integrate the conceptual knowledge and problem solving procedures (Yuliana et al., 2020).

Efforts to improve students' physics problem-solving abilities have been made through the implementation of various innovative learning models such as Problem Based Learning (PBL), Discovery Learning, and the use of interactive digital media (Risamasu & Pieter, 2024). The PBL model has been proven to provide positive effects because it focuses on real-world problems and encourages students to construct knowledge independently (Herayanti et al., 2020). Furthermore, integrating PBL with digital media such as E-LKPD has been shown to increase students' motivation, participation, and learning outcomes, particularly in the context of physics problem solving (Risamasu & Pieter, 2024). The integration of digital media in physics learning has been shown to enhance students' motivation, engagement, and problem-solving

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performance. Digital books, multimedia scaffolding, virtual laboratories, and interactive learning platforms provide visual and contextual support that helps students better understand abstract physics concepts (Chen & Chang, 2020; Hamdani & Wulandari, 2020; Smith & Jones, 2022; Tsai & Shen, 2021)

While PBL and digital media have been studied for the improvement of learning outcomes, there is little evidence of research that focuses on the problem-solving skill of students in the area of temperature and heat, particularly at the indicator level of analysis. These studies have focused on achievement outcome measures or on the comparison of instructional designs, and they have done little to identify an area of need or the specific problem-solving process or stage that needs enhancement. The need for indicator level analysis is critical because it describes the area of need and focuses efforts on the development of specific instructional objectives.

Consequently this study focuses on analyzing the problem-solving skills of the 11th-grade students on the topic of temperature and heat based on Heller's problem-solving indicators as a basis for the construction of a Problem-Based Learning model integrated with digital books. The originality of this study stems from the construct, as it comprehensively identifies students' challenges for each stage of problem-solving and ties the results to the instructional design of digital books integrated with PBL, thus supporting the attainment of SDG 4 through efficient, evidence-based teaching of physics.

RESEARCH METHOD

This study employed a descriptive quantitative approach supported by qualitative data, conducted as preliminary research. Before a digital book-assisted Problem-Based Learning (PBL) model is implemented and developed, preliminary research is used as an initial needs analysis to investigate students' current problem-solving skills and learning environments (Sianipar et al., 2023). This methodological approach is appropriate because, in order to ensure that the designed intervention addresses actual learning needs, instructional development necessitates a clear understanding of learners' initial conditions (Ayudha & Setyarsih, 2021).

This study does not only aim to describe the phenomena occurring in the field but also serves as a reference in designing the learning model that will be implemented in the next stage. This approach is relevant because development research requires a careful needs analysis before entering the design and implementation stages (Ayudha & Setyarsih, 2021)u.

Purposive sampling was used to select 105 eleventh-grade students for the study, which took place at State Senior High School 1 Sidoarjo during the odd semester of the 2025–2026 academic year. This sample size and one school were chosen based on factors such as curriculum alignment, accessibility, and the heterogeneity of students' academic abilities, which allowed for an initial yet representative mapping of problem-solving skills within the studied context. Nevertheless, this sampling strategy also implies limitations in terms of external validity, as the findings may not be generalized to all senior high school contexts.

Data were collected using by three methods were used to gather data: (1) an essay-based problem-solving test that was created using Heller's five indicators; (2) a four-point Likert-scale questionnaire that assessed students' perceptions and educational experiences; and (3) semi-structured teacher interviews (Fadhila & Alé, 2024). To make sure the instruments accurately reflected the intended constructs, three expert validators validated the instruments using content relevance and clarity criteria. To guarantee the accuracy and consistency of the data gathered, this validation procedure was crucial. The questionnaire used a four-point Likert scale ranging from strongly disagree to strongly agree, which is commonly applied in educational research to measure students' perceptions and attitudes (Joshi et al., 2015).

While qualitative data from interviews was examined to corroborate and interpret the quantitative results, quantitative data from the tests and questionnaires were analyzed descriptively using percentages and mean scores to characterize students' problem-solving profiles. Triangulation was made possible by the integration of these data sources, which increased the validity of the study's conclusions and offered a more thorough picture of students' preparedness for PBL implementation with the help of digital books.

The research instruments included essay tests, questionnaires, and interview guidelines validated by three expert validators. Instrument validation is an essential step in educational research to ensure the accuracy of the measurement tools before they are used in data collection (Risamasu & Pieter, 2024).

The data analysis technique was conducted qualitatively and descriptively based on the results of the tests, questionnaires, and interviews. Descriptive analysis was chosen because it can provide a clear picture of the students' initial conditions, particularly regarding their readiness to participate in PBL-based learning assisted by digital technology (Sholihah & Wardani, 2025). The steps used in this research can be seen in Figure 1.

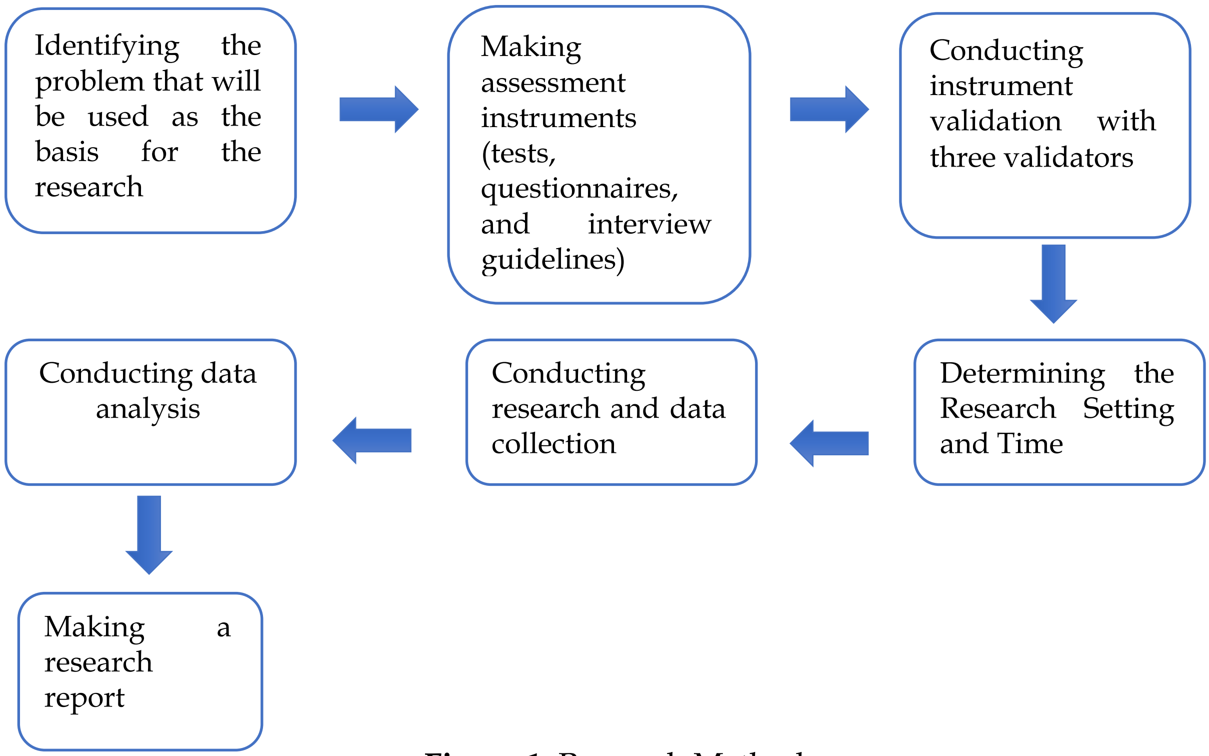

Figure 1. Research Method

RESULTS AND DISCUSSION

Results

Results of the Test Assessment Instrument

One of the methods used to assess students' problem-solving skills is through test-based assessment instruments. Students were given five essay questions, each of which was broken down into five problem-solving indicators according to Heller. This test instrument was administered because students' creativity in responding to the problems, as a form of applying problem-solving skills, naturally varies. After the students completed the tasks, the results were obtained as follows:

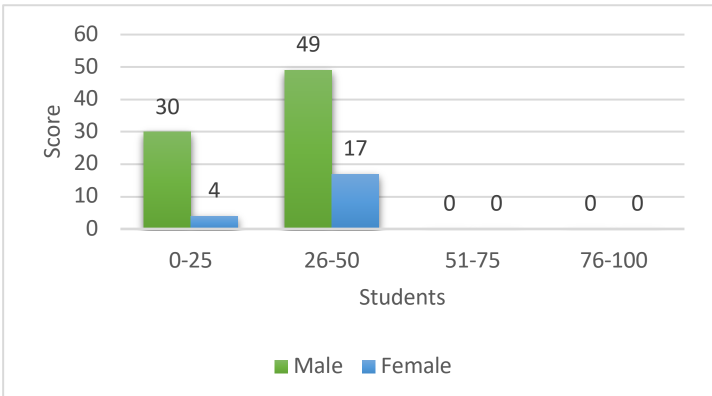

Figure 2. Problem-Solving Test Results

Based on Figure 2, it is known that the test was taken by 105 eleventh-grade students from State Senior High School 1 Sidoarjo. The results obtained after the test was administered show that 34 students consisting of 30 male students and 4 female students received scores of 0–25, which fall into the poor category. A total of 66 students consisting of 49 male students and 17 female students received scores of 26–50, which fall into the fair category, and 0 students received scores of 51–100, which fall into the good and very good categories. These results were obtained from the scoring of each question, where each question consisted of five indicators, and each indicator was worth 4 points. The total score for one question, if the students were able to solve all five indicators, was 20, and the overall total score for all questions was 100.

From the data presented, it can be concluded that most students were not yet able to apply problem-solving skills when working on physics questions. The students were not able to classify one problem into the five existing problem-solving indicators, namely: (1) Visualize the problem, (2) Physics description, (3) Plan a solution, (4) Execute the plan, and (5) Check and evaluate. In addition, the five questions given were designed with a HOTS (High Order Thinking Skills) type, which created a higher level of difficulty for the students. The classification of which indicators were well understood by the students and which were not yet mastered is shown in Figure 3.

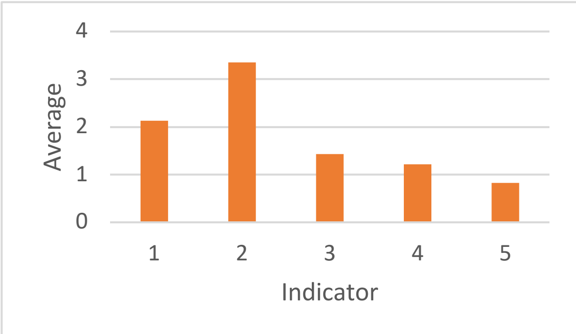

Figure 3. Average Results of Students' Problem-Solving Indicators

Overall, the results of the analysis show that students' strongest abilities lie in the indicator of Physics Description, while their abilities begin to decline starting from the Plan a Solution indicator. These findings indicate that students already possess good conceptual understanding of physics content; however, they still encounter difficulties in applying these concepts to solve problems procedurally and quantitatively. The decline in students' performance starting from the planning and evaluation stages is consistent with previous findings showing that students tend to struggle in selecting appropriate strategies and reflecting on their solutions, even when they possess adequate conceptual knowledge (Docktor et al., 2015; Henukh et al., 2024; Ouyang & Schunn, 2020).

The findings show that most students have low to moderate problem-solving skills, and none of them fall into the good or very good categories. Analysis at the indicator level reveals that students perform relatively well in the physics description stage, suggesting adequate conceptual recognition of relevant variables and principles. However, during the planning, execution, and evaluation phases, performance drastically decreases.

From a cognitive standpoint, these results imply that although students have declarative knowledge of physics concepts, they lack the procedural and metacognitive abilities necessary to properly plan and assess solutions. According to problem-solving theory, the planning stage requires students to select and organize appropriate strategies, which involves higher cognitive load and strategic reasoning (Docktor et al., 2015). The observed difficulties in this stage may be attributed to limited exposure to structured problem-solving frameworks in prior instruction, as well as teacher-centered learning practices that emphasize formula application over strategic reasoning.

The results above were obtained from students' responses based on the problem-solving indicators proposed by Heller, which include:

Visualize the Problem

In this first indicator, students are expected to visualize the physics problem in the form of drawings and to explain the physics concepts contained within the problem.

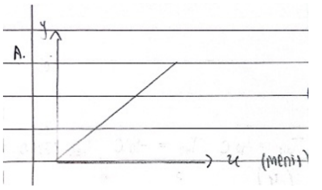

Figure 4. Example of student responses on the indicator visualize the problem

From the figure 4, the students are able to visualize the physics problem in the form of a simple diagram/graph. However, the students' answer is not entirely accurate because no labels are provided on the x-axis and y-axis.

Physics Description

In the second indicator, students are expected to write down the variables contained in the problem to help them carry out the subsequent steps more easily.

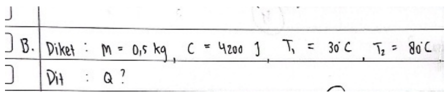

Figure 5. Example of student responses on the indicator physics description

From Figure 5, it is known that the students have been able to describe the problem into physical concepts by identifying the variables given in the question.

Plan a Solution

Furthermore, in this third indicator, students are expected to determine which solution should be used to solve the problem in the question. Students are required to identify which physics equations can be applied to solve the given problem.

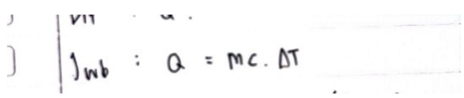

Figure 6. Example of student responses on the indicator plan a solution

From the figure 6, it is evident that the students have been able to identify the equation that can be used to solve the given physics problem.

Execute the Plan

In the fourth indicator, students are expected to solve problems using the solutions they have obtained from the third indicator.

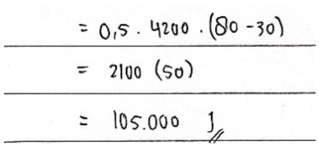

Figure 7. Example of student responses on the indicator excute the plan

From the figure 7, the students were able to use the solution from the fourth indicator, allowing them to produce the correct answer to the problem in the question.

Check and Evaluate

In the fifth indicator, students are expected to be able to recheck their work and then conclude whether the answers they provided are appropriate.

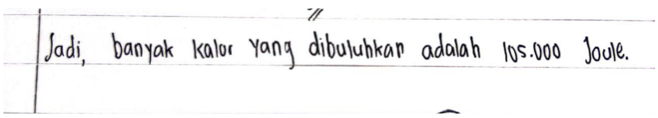

Figure 8. Example of student responses on the indicator check and evaluate

From the image above, students can conclude that the results they worked on are correct and appropriate.

Discussion

Problem-Solving Test Questionnaire

A total of 105 students were given a questionnaire consisting of 14 statements to measure their responses to physics learning and their ability to solve problems based on problem-solving indicators. The questionnaire also included students' views regarding the teaching and learning process in the classroom. Each statement was answered using a four-point Likert scale ranging from 1 (Strongly Disagree), 2 (Disagree), 3 (Agree), to 4 (Strongly Agree).

From the administered questionnaire, the results showed that the majority of students believed that (1) Physics is an interesting and challenging subject to learn, (2) The teacher still lacks in connecting physics material to everyday life, (3) Students make little effort to find solutions to the physics problems given, (4) Students lack confidence when answering physics questions in class, (5) Students participate less during learning and tend to listen more, (6) Students are more enthusiastic about learning when working in groups rather than individually, (7) The learning media used so far are considered less varied, (8) Students often use technology or digital resources to support their physics learning, (9) Students are more motivated to learn physics when using interactive digital media, (10) Students have difficulty understanding the situations and information presented in physics problems, (11) Students are less able to represent physics situations (for example, through diagrams, sketches, or symbols) before calculating, (12) Students are less capable of planning logical and systematic steps to solve physics problems, (13) Students tend to perform calculations carefully and recheck their work, and (14) Students are fairly capable of evaluating whether the answers they produce are reasonable based on relevant physics concepts.

Table 1. Student Questionnaire Results

Question	Precentage (%)			
	1	2	3	4
Physics is an interesting and challenging subject to learn.	4	8	50	28
My teacher often relates physics material to everyday life, making it easier for me to understand.	6	25	48	22
I try to find solutions to every physics problem given by the teacher.	12	48	22	18
I feel confident when answering physics questions in class.	19	41	31	9
I actively participate during physics learning, not just listen.	16	38	31	14
I am more enthusiastic about learning when working in groups to solve physics problems.	9	15	47	30
The learning media used by the teacher are varied and help me understand physics concepts.	9	47	30	15
I often use technology or digital resources to support my physics learning.	1	12	51	35
I am more motivated to learn physics when using interactive digital media.	2	25	42	31
I understand the situations and information given in physics problems before starting to solve them.	13	43	31	12
I can represent physics situations (for example, through diagrams, sketches, or symbols) before calculating.	17	38	34	10
I can plan logical and systematic steps to solve physics problems.	12	43	34	10
I perform calculations carefully and recheck my work.	14	34	39	12
I evaluate whether my answers are reasonable based on relevant physics concepts.	9	34	38	19

Teacher Interview

To support the data obtained from the student questionnaire, interviews were conducted with the physics teacher at State Senior High School 1 Sidoarjo. The interview was carried out by asking several questions directly. Based on the interview results, it was found that students often perceive physics as a fairly difficult subject. During the teaching and learning process, students tend to listen more rather than actively participate in class, they also feel embarrassed to ask questions when facing difficulties during the lesson. As a result, the teacher more frequently provides written practice exercises rather than engaging in direct discussions in class. The practice questions given by the teacher are quite varied, ranging from single multiple-choice, complex multiple-choice, to essay questions. However, questions specifically designed to measure students' problem-solving skills have never been administered directly. The teachers agreed that students' problem-solving skills need to be assessed specifically, but certain limitations have prevented such assessments from being conducted.

As teachers, they are expected to synthesize appropriate learning models and media to be used during instructional activities. So far, the PBL model is considered suitable for use in the learning process. The use of PBL must be supported by interactive media that can increase students' enthusiasm for participating in physics learning. Up to now, interactive media such as PowerPoint and Quizziz have often been used to support the learning process. However, the use of digital books is still rare. Learning activities are still centered on printed textbooks, and students frequently seek additional learning resources from social media such as TikTok, YouTube, or X.

The questionnaires and interviews with teachers further confirm these results. Students reported lack of confidence, little active participation, and difficulty with planning step-by-step systematic solutions. At the same time, the teachers admitted that problem-solving skills are very rarely explicitly evaluated in their classroom practices. This triangulation of data reinforces the case that students' problems extend beyond individual cognitive abilities and are more largely the product of the teaching, the environment and the problem at hand.

These findings relate directly to the teaching design of the digital book–assisted PBL model. More explicitly, digital books can integrate scaffolding functions such as guiding questions, pictures, examples, and evaluative questions to help students at the planning and evaluating phases. With these supports integrated in the activities, students in PBL can be taught to internalize and utilize systematic strategies for problem solving to overcome their weaknesses.

Previous Studies

This study aims to examine the effectiveness of developing a Problem-Based Learning (PBL) model assisted by a digital book in improving high school students' physics problem-solving abilities. To achieve this, a review was conducted on several previous studies published in national and international journals between 2020 and 2024. A summary of the latest research findings is presented in the following table.

Table 2. Five Year Article Review

Author	Research Objectibe	Research Method	Findings
Saprudin et al. (2021)	To describe the results of a literature review on the use of e-books in physics learning and to provide a reference for the future development of physics e-books.	Literature Review	1. E-books are used to improve motivation, literacy, critical thinking skills, creativity, and learning outcomes. 2. Commonly used software includes Flip PDF Professional, Sigil, 3D Pageflip, Articulate

Author	Research Objectibe	Research Method	Findings
			Storyline, Kotobee Author, and others. 3. Educational theories frequently applied include the scientific approach, discovery learning, inquiry, PBL, and problem solving. 4. Physics topics commonly targeted include motion, momentum, temperature and heat, dynamic fluids, and electric circuits.
Firmansyah et al. (2022)	To determine the effect of implementing the Problem-Based Learning model on high school students' physics problem-solving abilities.	A quantitative approach with a quasi-experimental design.	The PBL model improved students' physics problem-solving abilities by 88% compared to conventional learning.
Risamasu & Pieter (2024)	To develop and test the validity, practicality, and effectiveness of PBL-based E-LKPD for use in physics learning.	R&D (Research and Development) study using the 4-D model (Define, Design, Develop, Disseminate) conducted up to the development stage.	PBL-based E-LKPD has been proven effective in improving students' physics problem-solving abilities.
Ayudha & Setyarsih (2021)	To analyze indicators of problem-solving skills, effective physics learning models and media, as well as the causes of students' difficulties in solving problems.	A literature study with bibliometric analysis.	Students' difficulties are caused by the teacher's conventional methods, which are not student-centered and make limited use of technological media.
Ina Yuliana, Rian Priyadi, Zulhadi,	To analyze students' problem-solving abilities on the topic of temperature and	Quantitative descriptive research.	Students' problem-solving abilities are classified as low. Most are only able to

Author	Research Objectibe	Research Method	Findings
Kaslam, & Mahruf (2020)	heat in high school.		write descriptive information and apply formulas without a deep understanding of physics concepts. Students are categorized as novice problem solvers because they are not yet able to connect concepts with problem-solving processes.
Nova Allysa Qotrunnada & Binar Kurnia Prahani (2022)	To analyze the profile of high school students' problem-solving abilities as a basis for implementing a digital book-assisted Problem-Based Learning (PBL) model on the topic of dynamic fluids.	Qualitative descriptive approach.	The majority of students (133 out of 143) have low problem-solving abilities (0–40), with only one student in the high category. The strongest indicator is Create a Drawing, while the weakest is Conceptualize the Strategy. Both teachers and students stated that PBL with a digital book could be a solution to improve problem-solving skills.
Junita (2021)	To improve students' learning outcomes on the topic of temperature and heat through the use of thermometer teaching aids.	Classroom Action Research	The use of thermometer teaching aids makes learning more engaging and increases students' activity and motivation.
Rahayu Suciati, Sarwanto, & E. Y. Ekawati (2024)	To describe the quality of students' physics textbooks on the topic of temperature and heat using the STRS (Science Textbook	Qualitative descriptive approach.	1. Book A and Book B were rated as fairly appropriate according to the STRS aspects. 2. Book A was rated as satisfactory

Author	Research Objectibe	Research Method	Findings
	Rating System) instrument.		(100%) but has shortcomings, including incomplete material and errors in specific heat data. 3. Book B was rated 80% satisfactory and 20% fairly satisfactory, with shortcomings in question variety and errors in the concept of heat. In conclusion, both books are suitable for use with some improvements needed in concept accuracy and illustration presentation.
Henukh, Astra, Jua, & Susilawati, (2024)	To determine students' problem-solving skills after participating in problem-based learning on the topic of temperature and heat in high school.	Quantitative descriptive research.	Students' problem-solving abilities averaged 65.3% after the learning process, indicating an improvement compared to the pretest. Students still tended to experience difficulties in the stages of strategy planning and checking their results. The researcher concluded that students need to be continuously accustomed to using problem-solving steps in physics learning.
Khairun Nisa, Santri Adi Putri, &	To identify research trends related to problem-solving	Qualitative research with a systematic literature review (SLR)	The year 2020 showed the highest increase in the

Author	Research Objectibe	Research Method	Findings
Heru Kuswanto, (2024)	skills in physics learning between 2017 - 2022, including the most frequently studied physics topics, the types of research conducted, and the grade levels of students who were the research subjects.	approach using content analysis and PRISMA-P guidelines.	number of publications on problem-solving skills in physics. The most frequently used subjects were 11th-grade high school students, and the most commonly studied topics were general physics and temperature and heat. The dominant research types were quantitative and R&D. This study recommends increasing the number of qualitative studies and developing valid instruments to measure problem-solving skills.

Several studies have shown that the implementation of the Problem-Based Learning (PBL) model by teachers has a significant positive impact on improving students' problem-solving abilities. Based on the conducted research, it is concluded that the use of this learning model is effective in systematically enhancing problem-solving skills as well as students' learning outcomes in physics. Therefore, the implementation of PBL supported by digital media is considered a promising solution, as digital learning environments can facilitate collaborative learning, representation skills, and independent problem solving (Lee & Park, 2022; Wang & Liu, 2021; Yeh & Lai, 2023).

CONCLUSION

Fundamental Findings: This study shows that most 11th graders exhibit low or moderate problem-solving skills regarding temperature and heat. Difficulties occur at the planning and evaluation stages. While the students did describe the relevant physics concepts, most failed to describe the steps that would help them solve the problem, and reflect whether the solution was accurate. **Implications:** These findings suggest that there is insufficient problem-solving instruction, and that students' need to be actively engaged in the problem-solving framework, rather than be given an explanation of the concepts. The combined use of a Problem-Based Learning model and digital books resolves the need to contextualize the problem, to collaborate, and most importantly, to provide scaffolding that strengthens the students' procedural and metacognitive skills. In terms of SDG 4, this approach contributes to the learner-centered improvement of the effectiveness and quality of instruction in physics. The study is confined to one school, and one physics topic; this focus limits the findings' applicability. **Limitations:** This study was conducted in a single school with a limited sample and focused only on the topic of temperature and heat. Therefore, the findings may not be generalizable to broader educational contexts or other physics topics. **Future Research:** Future studies should use experimental or quasi-experimental methodologies in multiple school settings and examine specific digital features such as simulations and adaptive feedback to enhance students' problem-solving skills at each indicator level.

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