

Development of A Problem-Based Learning-Based Heat Student Worksheet to Enhance Senior High School Students' Creative Thinking Skills

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Article Info	Abstract
Article history: Received: December 8, 2025 Accepted: May 30, 2026 Published: July 29, 2026 Keywords: Creative thinking Heat Problem-based learning Student worksheet This article is licensed under a Creative Commons Attribution-Share Alike 4.0 International license © 2026 Jurnal ilmiah Pendidikan Fisika	Creative thinking is a crucial 21st-century skill that must be developed through classroom learning. However, in practice, physics learning is still largely dominated by conventional approaches, resulting in suboptimal stimulation of this skill. This study aims to determine the effectiveness of a problem-based learning (PBL)-based student worksheet on the topic of heat in improving senior high school students' creative thinking skills. This study employed a research and development method using the 4D model. The product was developed based on the PBL syntax and creative thinking indicators, namely fluency, flexibility, and originality. The trial subjects consisted of 27 grade XI students. The instruments used included validation sheets, lesson implementation observation sheets, and pre-test and post-test for creative thinking skills. The validation results showed that the student worksheet belongs to the <i>very valid</i> category, with an average score of 3.78 and high reliability. The practicality results indicated that the student worksheet is <i>highly practical</i> to use, with an average implementation score of 3.65. The effectiveness of the student worksheet was demonstrated by an N-gain score of 0.45 for creative thinking skills, which falls into the moderate category. Therefore, the developed PBL-based heat student worksheet is declared effective in enhancing students' creative thinking skills in physics learning. This student worksheet is feasible for use as an innovative teaching instrument that promotes active engagement and contextual problem-solving.
To cite this article: Muliyanti, Suyidno, & Mahtari, S. (2026). Development of a problem-based learning based heat student worksheet to enhance senior high school students' creative thinking skills. <i>Jurnal Ilmiah Pendidikan Fisika</i>, 10(2), 293-304.	

INTRODUCTION

Education is a strategic aspect in shaping quality human beings who are able to adapt to the dynamics of modern life. In the era of global connectivity and the Industrial Revolution 4.0, the *Merdeka Curriculum* emphasizes strengthening 21st-century competencies, particularly analytical ability, innovation, interaction, and collaboration (4C). Among these competencies, creative thinking skills are considered essential in facing digital challenges and global competition ([Diniati & Supratiyoko, 2023](#)). Learners with creative thinking abilities tend to generate new ideas, solve problems innovatively, and adapt effectively in complex situations ([Adiilah & Haryanti, 2023](#)). Therefore, teachers play a crucial role in designing learning experiences that foster creativity through appropriate approaches, strategies, and learning tools ([Sulastri et al., 2022](#)).

There is an immediate urgency to reform the current paradigm of physics education. If physics instruction remains teacher-centered and solely focused on rote mathematical memorization, students will miss critical opportunities to develop their creative thinking capacities. Challenges in the modern era do not present themselves as multiple-choice

questions; instead, they appear as complex, open-ended problems that demand innovative and out-of-the-box solutions. Delaying the implementation of instructional instruments that explicitly nurture this creative drive will result in graduates who are proficient in computation but ill-equipped to generate novel solutions for real-world societal challenges. Learning in schools is still largely dominated by conventional, teacher-centered approaches, making students tend to be passive, reliant on memorization, and less capable of connecting physics concepts with everyday phenomena ([Riordan & Rapih, 2026](#)). Observations indicate that students' creative thinking skills remain low, as seen in their difficulties with fluency, flexibility, originality, and elaboration of ideas. Physics is essentially a discipline that is very closely related to the ability to solve problems (*problem-solving*) to understand natural phenomena comprehensively, not just memorize mathematical formulas. There is a strong match between problem-solving characteristics in physics and creative thinking skills. When faced with complex physics problems, students are required to be able to analyze the situation from various points of view (*flexibility*), formulate various alternative solutions (*fluency*), and come up with unique and applicable ideas or solutions (*originality*). The inseparable relationship between the process of solving physics problems and the demand for divergent thinking is a strong reason why learning innovations to train creative thinking skills are so urgent and important to be carried out in this research. This condition is influenced by monotonous teaching methods and less contextual learning materials. PBL offers a potential solution by presenting contextual problems as the basis of learning, training students' inquiry, collaboration, and creativity ([Andriyani et al., 2020](#)).

One medium that supports PBL implementation is the Student Worksheet, as it guides students to solve problems, explore key concepts, and construct knowledge independently ([Lisnawati et al., 2022](#)). In physics learning, a PBL-based student worksheet is relevant for heat topics, which cover thermal energy, its transfer through conduction, convection, and radiation, as well as its relation to temperature and changes in states of matter ([Sutresna, 2020](#)). The concept of heat is closely related to daily life, such as cooking, fever, air cooling, and industrial technology, yet students often struggle to understand it because the learning process remains theoretical. Through PBL, these phenomena can be used as learning triggers that challenge students to think creatively in seeking scientific solutions ([Risni et al., 2021](#)).

The integration of heat and temperature topics, the PBL model, and student worksheets as the primary instructional instrument represents a vital and synergetic combination in this study. First, the topic of heat is highly relevant due to its abundant connection to everyday contextual phenomena (such as thermal expansion, heat transfer in cooking, and phase changes), providing an ideal foundation to trigger students' curiosity. Second, the PBL model serves as an effective pedagogical framework to process these contextual issues by actively placing students in authentic problem-solving environments. Third, to ensure that the problem-solving process remains systematically structured, the student worksheet acts as an essential scaffolding tool. Without a student worksheet specifically designed to target fluency, flexibility, and originality, students' exploration risks merely achieving basic conceptual understanding without successfully stimulating higher-order creative thinking skills.

Research conducted earlier has demonstrated the benefits of PBL-oriented student worksheets across a range of science topics, including fluid dynamics ([Raudhati, 2024](#)), acids and bases ([Mariyana, 2023](#)), and elasticity and Hooke's Law ([Audin et al., 2023](#)). The majority of these prior studies utilized PBL worksheets primarily to enhance general cognitive learning outcomes or critical thinking skills. There is a noticeable paucity of research that explicitly unpacks and designs physics PBL worksheets—particularly on the

topic of heat—that systematically integrates creative thinking indicators (fluency, flexibility, and originality) within each learning syntax. Consequently, this study addresses this literature gap by developing a PBL-oriented student worksheet where contextual thermal phenomena serve not merely as illustrative examples but as structured catalysts designed to train students to generate flexible and original ideas. The novelty of this study lies in developing a PBL-based student worksheet grounded in contextual everyday phenomena, designed according to creative thinking indicators: fluency, flexibility, and originality.

The physics student worksheet developed in this research employs the PBL model to encourage students' active engagement in solving contextual problems. This study aims to describe the feasibility of a PBL-oriented physics student worksheet on heat material as an effort to enhance students' creative thinking skills.

METHODS

This study employed the Research and Development (R&D) method using the 4D development model (Define, Design, Develop, and Disseminate) proposed by Thiagarajan, Semmel, and Semmel. The research was limited to three stages: Define, Design, and Develop ([Waruwu, 2024](#)). The product developed in this study was a student worksheet on the topic of heat, based on the PBL approach, with the aim of optimizing students' creative thinking skills. The student worksheet was structured according to the PBL syntax, which includes: (1) introducing students to the issue being raised, (2) organizing students for learning activities, (3) conducting independent exploration, (4) developing and presenting a product or solution, and (5) analyzing and evaluating the process of problem-solving. The flow of the 4D development model is illustrated in Figure 1.



Figure 1 The 4D Model Diagram ([Thiagarajan et al., 1974](#))

The product testing design employed a one-group pretest–posttest design. The research subjects consisted of 27 students from class XI Science at a public senior high school located in Banjarmasin. The study was conducted during the first semester of the 2024/2025 academic year. The creative thinking ability test instrument consisted of open-ended questions based on three indicators: fluency, flexibility, and originality. Its validity was assessed by three validators (two experts and one practitioner), and the average validation score was compared with criteria, indicating that the instrument was valid. Reliability was evaluated using Cronbach's Alpha ([Arikunto, 2016](#)), showing an acceptable level of consistency. The validated and reliable instrument was administered before and after the student worksheet-based learning to measure students' creative thinking development, and the results were analyzed using ([Hake, 1998](#)) Normalized Gain (N-gain) formula. Table 1 presents the N-gain categories according to ([Hake, 1998](#)).

Table 1 N-Gain categories ([Hake, 1998](#))

N-Gain	Criteria
$\langle g \rangle > 0.7$	High
$0.7 \geq \langle g \rangle \geq 0.3$	Medium
$\langle g \rangle < 0.3$	Low

Students' creative thinking ability achievements from the pretest and posttest were categorized according to the criteria shown in Table 2 ([Hu & Adey, 2002](#))

Table 2 Creative thinking ability assessment categories ([Hu,& Adey, 2002](#))

Indicator	Score	Criteria
Fluency	0	Does not provide any answer
	1	States one idea, suggestion, or alternative answer
	2	Provides several ideas or suggestions that are similar or not very diverse
	3	Produces three different ideas or alternative answers
	4	Produces four varied ideas or alternative answers
Flexibility	0	Does not provide any answer
	1	Gives one logical and relevant answer, but only from a single point of view
	2	Gives two logical and relevant answers from different perspectives
	3	Provides three logical and relevant answers by looking from various viewpoints
	4	Provides four logical, accurate, and appropriate answers from multiple perspectives
Originality	0	Does not provide any answer
	1	Produces a common, logical, and problem-appropriate idea
	2	Produces a somewhat different, interesting, reasonable, and relevant idea
	3	Presents several new and unique ideas that are interesting but less appropriate to the problem
	4	Generates several new ideas that are different, interesting, reasonable, and highly relevant to the problem

RESULTS AND DISCUSSION

The product developed in this research is a physics student worksheet oriented toward PBL on the topic of heat, aimed at improving students' creative thinking skills. The student worksheet was developed and structured based on the Merdeka Curriculum by incorporating problem-based learning syntax. This student worksheet was created using word processing and graphic design software, making it visually appealing and easy to use by both teachers and students. This student worksheet is designed to guide students in contextual learning activities that are oriented toward problem-solving.

The physics student worksheet that was designed includes general information, a concept map, user instructions, student reading materials, problem-based activities, reinforcement questions, answer keys, an author biography, and references. This student worksheet is also equipped with creative thinking indicators consisting of fluency, flexibility, and originality.

The learning model implemented in this student worksheet follows the five phases of problem-based learning, namely (1) orienting students to the problem, (2) organizing students, (3) guiding group investigation, (4) developing and presenting the work, and (5) analyzing and evaluating the problem-solving process. The student worksheet is arranged for three meetings, covering the subtopics of heat, thermal expansion, and heat transfer. The updates and novelties of the PBL-oriented physics student worksheet are presented in Table 3.

Furthermore, there is a fundamental difference between the student worksheet developed in this study compared to the PBL-based student worksheet in previous studies. While previous research on dynamic fluids and elasticity focused primarily on conceptual understanding and general problem-solving, this student worksheet is specifically designed to unpack the distinct indicators of creative thinking—namely fluency, flexibility, and originality—within the context of temperature and heat ([Audin et al., 2023](#); [Raudhati, 2024](#)). A conventional student worksheet or other PBL student worksheet often only stops

at finding a solution to the problem. On the contrary, this student worksheet presents contextual phenomena that are close to students' daily lives—such as the phenomenon of dew, fever handling, and the process of water heating—as triggers for exploration. In addition, the student worksheet is equipped with reinforcement questions that are deliberately designed to force students to think about more than one perspective of the answer (flexibility) and formulate unique or unthinkable ideas (originality), an aspect that is rarely explored in depth in physics student worksheets in general

Table 3 Updates of PBL-oriented physics student worksheet

No	Novelty
1	The student worksheet is designed to enhance students' creative thinking skills by incorporating indicators of fluency, flexibility, and originality through the completion of contextual problems.
2	The student worksheet is developed based on the syntax of problem-based learning, emphasizing collaboration and active student engagement.
3	The student worksheet is equipped with reinforcement questions and answer keys that support concept mastery and the development of creative thinking skills.

Validity

The results of the validation test calculations for the student worksheet can be seen in Table 4.

Table 4 Student worksheet validation results

Aspect	Validation		Reliability	
	Score	Category	r11	Category
Format	3.83	Very valid	0.60	High
Content	4.00	Very valid		
Language	3.67	Very valid		
Presentation	3.94	Very valid		
Graphics	3.47	Very valid		

The validation results indicate that the PBL-oriented heat student worksheet developed falls into the “very valid” category in terms of content, language, presentation, and graphics, with high reliability. This proves that the student worksheet has been designed in a systematic and contextual manner and is aligned with the needs of 21st-century learning, particularly in fostering students' creative thinking skills ([Manurung & Marini, 2023](#)). The student worksheet consists of three activity topics: heat, thermal expansion, and heat transfer, each of which includes creative thinking indicators in the form of fluency, flexibility, and originality ([Wibowo, 2023](#); [Khotimah dkk., 2023](#)). By presenting real-life phenomena such as dew, fever, and water heating, students are facilitated to think both critically and creatively in seeking solutions through the stages of PBL. The PBL approach is capable of stimulating students to generate flexible and original ideas in solving contextual problems ([Sagilah dkk., 2023](#)).

In addition, the validity of supporting instruments such as the lesson plan and learning outcome test also falls into the “very good” category. The lesson plan meets the format, content, and language aspects and is declared consistent and suitable for use after revisions were made based on the validators' suggestions ([Khakim dkk., 2022](#)). The learning outcome test and the creative thinking ability test were assessed as being aligned with the indicators of fluency, flexibility, and originality, and both demonstrated high validity and reliability ([Khotimah dkk., 2023](#)). The quality of the instrument is further strengthened by its compliance with didactic, constructional, and technical requirements, alongside the BSNP standards for content feasibility, presentation, language, and graphics ([Aliyah dkk., 2021](#); [Ulya & Rusmini, 2022](#)) further strengthens the quality of the instrument. Therefore,

it can be concluded that the PBL-based student worksheet developed is not only valid in terms of content and construct but also possesses novelty by integrating PBL syntax with real-life contexts, in alignment with the demands of the Merdeka Curriculum and 21st-century learning ([Chintyawati & Perdana, 2024](#)).

Practicality

The implementation of learning activities using the student worksheet over three meetings is presented in Table 5.

Table 5 Student worksheet practicality

Observation Aspect	Meeting 1		Meeting 2		Meeting 3	
	Score	Category	Score	Category	Score	Category
Problem Orientation	4.00	VV	3.80	VV	3.80	VV
Organizing Students	3.50	VV	4.00	VV	4.00	VV
Guiding Group Investigation	3.67	VV	3.83	VV	3.67	VV
Developing and Presenting Work	2.83	V	3.00	V	3.50	VV
Analyzing and Evaluating	3.50	VV	3.87	VV	3.87	VV
Average Score	3.50	VV	3.70	VV	3.76	VV

Information: V = Valid, VV = Very Valid

The practicality of the PBL-based student worksheet on the topic of heat was assessed through classroom observation of learning implementation over three meetings using an instrument based on the PBL syntax ([Suyidno dkk., 2021](#)). The inter-observer reliability test showed a coefficient above 0.80, which falls into the very high category ([Arikunto, 2016](#)), indicating that the instrument is reliable. The observation results showed an increase in the average implementation score from 3.50 to 3.76, classified as *very good*, indicating that the PBL-based student worksheet is highly practical for classroom use. These findings confirm that systematically designed learning instruments can significantly enhance the effectiveness and efficiency of the learning process ([Muslimah, 2020](#)).

In each phase of the PBL syntax, the implementation was carried out very well, although the aspect of developing and presenting students' work showed a slightly lower score compared to the other phases. This was due to students' limited experience in preparing reports and the constraints of instructional time. However, there was an increase in the score from the first to the third meeting, indicating positive progress. Challenges in presenting results are common in PBL and require more intensive guidance ([Aisyah et al., 2025](#)). Overall, the high level of implementation demonstrates the practicality of the PBL-based student worksheet, a finding that corroborates prior research showing its capacity to support active participation, facilitate the learning process, and enhance conceptual understanding ([Audin dkk., 2023](#); [Raudhati, 2024](#)).

Effectiveness

The results of the pre-test and post-test showed a significant improvement in students' creative thinking skills. The calculation results for each creative thinking indicator in the pre-test and post-test are presented in Table 6.

Table 6 Pre-test and post-test results of students' creative thinking skills

Pre-test	Post-test
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Creative Thinking Indicators	Score	Category	Score	Category
Fluency	15.12	Not Good	72.83	Good
Flexibility	10.64	Not Good	56.02	Fairly Good
Originality	4.17	Not Good	26.89	Fairly Good

This is further supported by the n-gain data of students' creative thinking skills and learning outcomes, as presented in Table 7.

Table 7. Scores of Creative Thinking Ability and Learning Outcomes

Assessment	Pre-test		Post-test		N-Gain	
	Score	Category	Score	Category	Score	Category
Creative Thinking Ability	9.98	TB	51.92	CB	0.45	Medium
Learning Outcomes	22.04	KB	81.85	SB	0.75	High

(TB = Not Good, CB = Fairly Good, KB = Less Good, SB = Very Good)

The effectiveness of the PBL-based student worksheet on heat material was measured through the improvement of students' learning outcomes and creative thinking skills. The findings revealed a significant increase in the average scores from the pre-test to the post-test, demonstrating that the PBL model embedded in the student worksheet facilitates deeper conceptual understanding, as students are directly involved in the processes of problem identification, information exploration, and solution-seeking ([Masduriah, 2020](#)). The distribution of creative thinking abilities also showed a positive shift from the majority of students being in the poor category before the intervention to an increase in the proportion falling into the fair and good categories after the use of the student worksheet. These findings confirm that the PBL framework effectively fosters creative thinking skills by engaging students in problem-solving activities that demand active exploration and deep emotional involvement ([Khotimah et al., 2023](#); [Aji et al., 2024](#)). A deeper, indicator-specific analysis reveals distinct cognitive pathways stimulated by the PBL-structured student worksheet. Fluency achieved the most rapid and pronounced progression among all indicators. This notable improvement is directly attributable to the early stages of the PBL syntax embedded within the worksheet—specifically, Phase 1 (Orientation to the Problem) and Phase 2 (Organizing Students for Learning). In these phases, the student worksheet deliberately presents open-ended, ambiguous real-world anomalies related to heat, such as the mechanism of a fever or localized thermal expansion. Because these initial prompts are qualitative and low-stakes, they dismantle the students' fear of academic failure, encouraging them to generate a high volume of raw ideas and hypotheses without immediate self-censorship. Problem-based scaffolding effectively minimizes cognitive load during the initial brainstorming phase, thereby accelerating the fluid generation of ideas ([Khotimah et al., 2023](#)). In contrast, the development of flexibility required a more complex cognitive shift. While fluency relates to the quantity of ideas, flexibility demands that students categorize and approach a thermal phenomenon from multiple, distinct perspectives (e.g., shifting from macroscopic observations of heat transfer to microscopic particle behavior). The student worksheet facilitated this by structuring multi-tiered reinforcement questions across three distinct subtopics: heat, thermal expansion, and heat transfer. When confronted with a problem like structural damage due to thermal expansion, the worksheet forced students to pivot between architectural, material science, and mathematical viewpoints. However, as noted in the results, the progression of flexibility

was more gradual than fluency. This lag suggests that shifting cognitive categories in physics is deeply constrained by students' pre-existing misconceptions about heat—a divergence from prior findings where flexibility developed rapidly in fluid mechanics ([Raudhati, 2024](#)), likely due to fewer deeply entrenched intuitive misconceptions in that domain. The most compelling finding lies in the trajectory of the originality scores. Initially, during the pre-test, students' originality scores were near zero, indicating a profound deficiency in generating unique or unconventional solutions. This baseline suppression is typical of conventional, teacher-centered physics instruction, which conditions students to believe that physics problems possess only a single, formulaic path to a correct answer. This rigid conditioning completely paralyzes divergent thinking. Despite this low starting point, the post-test results revealed a dramatic relative increase in originality. The instructional catalyst for this surge was the deliberate inclusion of 'non-routine contextual triggers' and the requirement for a 'product solution' in Phase 4 of the PBL syntax (Developing and Presenting the Work). Rather than asking students to simply calculate heat capacity, the student worksheet challenged them to design hypothetical energy-efficient insulation or innovate daily cooling methods using localized materials. By explicitly asking students to provide solutions that were different or not commonly found in standard textbooks, the student worksheet acted as a structural permission slip for creative risk-taking. Even though their final scores remained lower than fluency in absolute terms, the sharp upward delta demonstrates that when physics worksheets provide explicitly scaffolded open spaces for unique ideation, students can rapidly break free from mechanical memorization. This observation strongly corroborates the framework that authentic problem-solving contexts are uniquely capable of transforming latent creative capacity into overt original output, even in structurally rigid disciplines like high-school physics ([Saqilah et al., 2023](#)). However, analysis of the creative thinking indicators showed that fluency experienced the most notable improvement, while flexibility and originality were still relatively limited ([Mariyana, 2023](#); [Raudhati, 2024](#)).

In addition, classroom observations revealed that uneven group dynamics, limited facilities, and a learning culture still accustomed to lecture-based methods became inhibiting factors for learning effectiveness. Students were initially passive but began to show confidence in expressing ideas by the third meeting. The implementation of the PBL syntax was also not yet fully optimal, particularly in the reflection stage, which was still limited to outcomes rather than metacognitive thinking processes. These findings confirm that the application of PBL can significantly improve creative thinking skills, although its success is heavily contingent upon implementation time, student readiness, and a supportive collaborative culture ([Milatti & Fitrihidajati, 2024](#); [Nurkhasanah et al., 2024](#); [Jayanti, 2022](#)). Therefore, the PBL-based student worksheet developed is considered sufficiently effective in improving learning outcomes and beginning to foster creative thinking skills, although it has not yet reached optimal levels. Optimization may be achieved through extended learning duration, reinforcement of creative thinking culture, habituation of balanced collaboration, and stronger teacher facilitation at each stage of the learning process.

CONCLUSION

Based on the results and discussion of the study, it can be concluded that the PBL-oriented student worksheet on heat material is suitable for use in learning to improve students' creative thinking skills. This is evidenced by its very high validity, meeting the aspects of format, content, language, presentation, and graphics, with an average validation score of 3.75. In terms of the high practicality, the student worksheet is categorized as highly practical, as indicated by the implementation of learning activities across three meetings,

with an average score of 3.65 in the "very good" category. Regarding the effectiveness, the student worksheet is declared effective, as shown by an N-gain score of 0.75 for the learning outcome test (high category) and an N-gain score of 0.45 for creative thinking skills (medium category). However, this study has several limitations, including the reduced number of research subjects due to incomplete pre-test and post-test participation, less optimal time management caused by post-break learning conditions, the need for more intensive teacher monitoring to ensure equal student participation in group work, and the relatively short implementation duration of three meetings, which may not fully capture the long-term development of students' creative thinking skills.

This study implies that the PBL-based student worksheet on heat material can be utilized by teachers as a teaching instrument that promotes active, collaborative, and creative learning in accordance with 21st-century demands. In addition to improving learning outcomes, this student worksheet also trains students' creative thinking skills through contextual problem-solving and can serve as a reference for future research in the development of learning materials for other physics topics.

CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest related to this study.

AUTHOR CONTRIBUTIONS STATEMENT

M was responsible for conceptualizing the study, providing the theoretical background, and drafting the manuscript. S and SM conducted the data analysis and performed the validation of the research instruments.

AI DISCLOSURE STATEMENT

The author used Google Scholar to identify and retrieve relevant reference sources, Google Translate to assist with language translation, and Grammarly to improve the clarity and grammatical accuracy of the English. All translated and edited text was carefully reviewed by the author, who takes full responsibility for the accuracy, integrity, and content of the published article. Furthermore, this manuscript was conceived, researched, written, and revised without the use of artificial intelligence (AI) technologies or AI-assisted writing tools.

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