*Volume 9 Number 2, August 2024, pp. 237~246*
*P-ISSN:2477-7935*
*E-ISSN: 2548-6225*
*DOI: 10.59052/edufisika.v9i2.36817*

# DEVELOPMENT OF STUDENT WORKSHEETS INTEGRATED WITH PBL-STEM ON TEMPERATURE AND HEAT MATERIAL

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**Article Info**
Recieved: 23 Aug 2024
Accepted: 27 Aug 2024
Publication: 27 Aug 2024

**Abstract :**
The purpose of this study is to create a Problem Based Learning approach integrated with Science, Technology, Engineering, and Mathematics (STEM), especially in the field of Physics. The goal is to improve students' creative thinking skills in learning about temperature and heat. The resulting Student Worksheets will be designed to be valid, practical, and effective. This study involves research and development activities using a 4-D model consisting of the stages of definition, design, development, and dissemination. This research was conducted at SMP Muhammadiyah Kartosentanan in the 2023/2024 academic year. Data collection was carried out through the use of validation sheets, student questionnaires, and test devices. Furthermore, data was collected using the N-Gain formula. PBL-STEM-based student worksheets were considered valid by the media validator with an agreement of 96%, the material validator 89%, and the instrument validator 95%. The feasibility analysis shows that the PBL-STEM-based student worksheets produced are very practical for students to use, as evidenced by the N-Gain results of 0.92 with a high category. This study concludes that the student worksheets developed based on PBL-STEM are valid, practical, and useful in improving students' creative thinking skills.

Keywords: Creative Thinking, PBL-STEM, Worksheet



## INTRODUCTION

Quality education will produce quality human resources. Therefore, the government has implemented several initiatives to improve educational standards, including changing the curriculum framework (Masykur, 2019; Yunita, 2024; Syamsiah, 2024). The Independent Curriculum is designed to provide students with a variety of intra-curricular learning opportunities, allowing them to optimize their learning experience, develop conceptual understanding, and improve their competencies (Arifin et al., 2021; Sunia, 2024; Fadhilah, 2024). According to Rahmadayanti & Hartoyo (2022), an independent curriculum provides autonomy to schools, instructors, and students, allowing them to engage in innovative, creative, and self-oriented learning, with teachers serving as catalysts. Teachers have an important role in improving the quality of student learning.

Teachers can improve the quality of learning by choosing the right learning model and learning media. An effective learning paradigm that can be used is the Problem-Based Learning Model. Syamsidah & Suryani (2018), defines the Problem-Based Learning Model as a pedagogical approach that encourages students to be actively involved in assessing and evaluating the problem-solving process, as well as exploring the relationship between knowledge and existing situations. The Problem-Based Learning paradigm is very suitable for the Biology learning process (Romita & Opeloyeru, 2023; Salsabila et al., 2024; Sonita & Febria, 2022). In addition to challenging Problem-Based Learning, STEM-based learning also involves active learning through challenge presentations (Wulandari, 2020; Yusnidar, 2023). STEM-focused educational activities can be implemented through the use of student worksheets and produce beneficial effects (Fitriani et al., 2017; Yusipa, 2024; Amin et al., 2023). STEM applications typically require the use of creativity, critical thinking, collaboration, and communication, sometimes referred to as the 4Cs. This allows students to find a variety of unique solutions to real-world challenges (Susanti et al., 2020; Hidayat et al., 2024; Pujono et al., 2024). The use of STEM approaches in education in Indonesia, especially in the field of Physics, is currently very limited.

Physics learning is a lesson that learns about everything in nature and how it interacts (Sudarisman, 2015; Fatonah et al., 2024; Angelia et al., 2023). Physics learning aims to provide information that contains facts, concepts, and processes that occur in nature so that students understand the nature around them. Problem Based Learning (PBL) in Physics learning is considered one of the innovative contextual learning designs, because it encourages students to learn Physics from real problems encountered around us, and trains students to become reflective learners (Asyhari, 2018; Masniari et al., 2023). Therefore, the role of teachers is very important in helping students to be able to understand the material through the right learning models and learning media.

One of the right teaching media to be used in the physics learning process is the Student Worksheet. Student worksheets consisting of activities assigned to students. These tasks include clear instructions and step-by-step guides for completing tasks, whether they involve theoretical or practical work. The use of Lembar kerja peserta didik can increase students' ability to think creatively (Aldila, 2017; Helida et al., 2023; Anggraeni et al., 2023). Creative thinking refers to the cognitive process that generates new ideas or thoughts that can then contribute to the acquisition of new knowledge and problem-solving (Abdurrozak et al., 2016; Safnowandi & Efendi, 2017; Maymunah, et al., 2023). The following are indications of innovative thinking, as identified by Suparman & Husen (2015), namely: 1) engaging in fluid thinking, generating many relevant thoughts or responses; 2) flexible thinking refers to the ability to generate a variety of ideas and explore many lines of thought; 3) fostering authenticity by providing answers that are unconventional and different from others; and 4) elaborative thinking refers to the process of developing, adding, and enriching concepts by involving detailed and thorough thinking.

Interviews with science teachers at Muhammadiyah Kartosentanan Junior High School showed that the application of STEM in Physics learning has not been implemented. The learning process only relies on teaching materials such as student worksheets and textbooks provided by the school. The student worksheets used contain many student activities, but these activities focus more on answering repetitive questions so that they are less effective and interesting for students. Based on the results of interviews about students' creative thinking skills, it appears that students' creative thinking skills are still relatively low, especially in biodiversity material. This is based on the results of previous interviews. Students still have difficulty understanding biodiversity information. To overcome this, one effective strategy is to include student worksheets in the STEM (Science, Technology, Engineering, and Mathematics) approach. The integration of PBL with STEM in worksheets has been shown to significantly improve students' creative thinking skills.

According to Hasanah (2021), integrating STEM into worksheets is intended to improve students' creative thinking skills in an interesting, logical, systematic, and original way. In addition, STEM-integrated worksheets can be used in the learning process. These findings are in line with research conducted by Lou et al. (2017), which showed that problem-based learning has a positive impact on attitudes towards STEM learning. Not only do students actively apply scientific and engineering knowledge, but they also acquire science and mathematics through STEM learning. Additionally, Problem-Based Learning improves students' ability to integrate and apply knowledge.

Therefore, using the STEM-based PBL paradigm for instruction presents an alternative approach to improve students' ability to think innovatively.

A number of studies have been conducted on the creation of PBL-STEM-based Worksheet, including a study project conducted by Meityastuti & Wijaya (2022). This research is included in the category of development research, especially using the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) paradigm (Abdurrahman & Ji, 2023; Hajarina, 2021; Hasibuan & Nugraha, 2023). It focuses on the design and development aspects of the research process (Astuti et al., 2024; Irfan, 2023; Oktadita et al., 2023). The purpose of this study was to create an worksheets learning tool that uses the STEM-based PBL model and Desmos application to teach students about triangles and quadrilaterals. These tools have been validated and can be used effectively to improve students' critical thinking skills during the learning process. From the research, both use R&D, which refers to the process of conducting research to build or improve a product. The difference between the worksheets research conducted by Meityastuti & Wijaya (2022) and other researchers lies in the use of the ADDIE development model, while the latter uses the 4D model proposed by Thiagarajan et al. (1974).

The novelty of this study lies in its special focus on the integration of problem-based learning (PBL) models with the STEM approach in Physics learning, which until now has been limited in its application. This study specifically targets improving students' creative thinking skills in biodiversity material, which is an area that has not been widely explored in the context of STEM-PBL integration. In addition, this study is also unique because it was conducted in a real context in a school, where traditional methods have proven to be less effective. This study not only developed STEM-PBL-based student worksheets, but also compared the effectiveness of various development models (such as ADDIE and 4D) in creating these student worksheets, something that has not been widely discussed in previous studies. Thus, this study offers a new, practical and focused approach to improving students' creative thinking skills through STEM-PBL integration in Physics learning.

## RESEARCH METHOD

This study focuses on the development of student worksheet products in Physics based on Problem-Based Learning and Science, Technology, Engineering, and Mathematics which aims to improve students' creative thinking skills, especially in the concept of biodiversity. This study uses the 4D development paradigm which includes four stages: the definition stage, the design stage, the development stage, and the dissemination stage (Thiagarajan et al., 1974).

At the definition stage, learning needs and objectives are identified in detail. Furthermore, the design stage includes the creation of student worksheet designs that integrate PBL and STEM elements. At the development stage, the designed student worksheets are validated by two expert lecturers and one teacher, to ensure the validity of the resulting product. This validation includes media validation and material validation, which are carried out through questionnaires given to lecturers and teachers. After the product is declared valid, it is distributed at the final stage, namely the dissemination stage.

Dissemination was carried out involving 20 eighth grade students at Muhammadiyah Kartosentanan Junior High School in the 2023/2024 academic year. At this stage, the practicality of the student worksheet was assessed through a questionnaire given to one teacher and 20 students, to evaluate the ease of use and benefits of the student worksheet. In addition, the effectiveness of the student worksheet was measured by comparing the pre-test and post-test scores of students' creative thinking skills, as well as calculating the N-Gain value to assess the increase in learning outcomes after using the developed student worksheet.

The instruments used in this study included validity tools evaluated by media and material experts, as well as practicality instruments measured through teacher and student responses. The effectiveness analysis was carried out based on the success of students in completing the learning outcome evaluation, which was measured by a creative thinking ability test before and after using the student worksheet. This student worksheet product is considered valid if the validation results from the lecturer show valid criteria, and is considered effective if there is a significant increase in student learning outcomes after the application of the student worksheet. The media, material, and instrument expert validation questionnaire instruments are presented in Table 1 below:

Table 1. Validation questionnaire grid for media, material and instrument experts

| Media Aspect | Material aspects | Instrument aspects |
|---|---|---|
| Student worksheet size | Material accuracy | Clarity |
| Student worksheet cover design | Material fluency | Content accuracy |
| Student worksheet content design | Encourage curiosity | Relevance |
| Total score obtained | Presentation techniques | Content validity |
| | Material suitability with Elements, and | No bias |
| | Learning Outcomes | Language |

Furthermore, the criteria for the validity and practicality of the PBL-STEM-based student worksheets are presented in the following table 2

Table 2. Criteria for Product Validity and Product Practicality

| Eligibility | | Practicality | |
|---|---|---|---|
| Score Range (%) | Category | Score Range (%) | Category |
| 75,01-100 | Very Valid | 81 – 100 | Very Practical |
| 50.01-75 | Quite Valid | 61 – 80 | Practical |
| 25.01-50 | Not Valid | 41 – 60 | Quite Practical |
| 0.0- 25 | Very Not Valid | 21 – 40 | Less Practical |
| | | 0 – 20 | Not Practical |

The grid for the student response questionnaire is as follows

Table 3. Questionnaire grid and student response categories

| Indicators | Category | Interval |
|---|---|---|
| Understanding of material, | Not Good | 14 – 24.5 |
| Engagement and motivation, | Quite Good | 24.6 - 35.0 |
| Relevance to Real Context, | Good | 35.1 – 45.5 |
| Collaboration skills | Very Good | 45.6 – 56.0 |

The data analysis technique in this study involved several steps to assess the validity, practicality, and effectiveness of PBL-STEM-based student worksheets. The validity of the worksheets was assessed through a validation test by media, material, and instrument experts, with the results analyzed using a percentage to determine the level of product validity. The practicality of the student worksheet was evaluated through a questionnaire filled out by one Physics teacher and 20 students, with the percentage of responses analyzed to measure how practical the student worksheet was. The effectiveness of the worksheets was measured by comparing the results of the students' pre-test and post-test, using the N-Gain formula to determine the increase in creative thinking skills. Student worksheets are considered valid, practical, and effective if the analysis results show values in the categories "valid," "very practical," and N-Gain is in the category "moderate" or "high." Then for data analysis using descriptive statistics in the form of percentages.

## RESULTS AND DISCUSSION

The definition stage involves interviews with Physics instructors and students at Muhammadiyah Junior High School. The goal is to determine the type of media used by teachers to facilitate learning and assess students' understanding of the material taught through this media. During the design stage, the focus is on planning the design of teaching materials, especially the development of PBL-STEM-based student worksheets. This involves several steps, starting with the preparation of general learning objectives, such as Learning Outcomes, Learning Objectives, and Learning Objectives Flow. In addition, specific goals are set, including enhancing students' creative thinking. The format of the student worksheet was selected by reviewing the existing student worksheet, and PBL-STEM-based biodiversity materials were selected to be included in the student worksheet. Finally, the design for the

PBL-STEM-based student worksheets was prepared as a teaching material for secondary school students.

The development stage involves the use of student worksheets in research as teaching materials. This stage focuses on the verification of the student worksheet which was developed to assess its suitability and effectiveness as a media tool. The validation test is carried out to determine the validity of the educational materials developed by the researcher. The validation test was carried out by four validators, including media validators, material validators, validation of question instruments, and questionnaire instruments. Media expert validation was carried out by Don Jaya P, M.Si.P., Kristina Uskenat, M.Pd., and M. Istanto. The average total validation results showed a very valid category with a percentage of 94% which can be seen in Table 3.

Table 4. Media Expert Validation Test Analysis.

| Validator | Score obtained | Maximum score | % | Mean | Category |
|---|---|---|---|---|---|
| M. Istanto | 108 | 112 | 96% | 94% | Very valid |
| Kristina Uskenat | 106 | | 95% | | |
| Don Jaya P | 105 | | 94% | | |

The validation of the material was carried out by Don Jaya P, M.Si.P., Kristina Uskenat, M.Pd., and M. Istanto. This shows that the category is very valid, has a percentage of 79% which is based on the results produced with the average validation results from material experts. The validation findings obtained by the material validator are presented in Table 5.

Table 5. Analysis of Material Expert Validation Test.

| Validator | Score obtained | Maximum score | % | Mean | Category |
|---|---|---|---|---|---|
| M. Istanto | 89 | 108 | 82% | 79% | Very valid |
| Kristina Uskenat | 86 | | 80% | | |
| Don Jaya P | 80 | | 74% | | |

The question instrument was endorsed by Don Jaya P, M.Si.P., Kristina Uskenat, M.Pd., and M. Istanto. The results of the validation determined by assessing the average assessment of the instrument specialist showed a very valid category, with a percentage of . It can be seen in Table 6.

Table 6. Instrument Validation Test Analysis

| Validator | Score obtained | Maximum score | % | Mean | Category |
|---|---|---|---|---|---|
| M. Istanto | 42 | 44 | 82% | 79% | Very valid |
| Kristina Uskenat | 41 | | 80% | | |
| Don Jaya P | 41 | | 74% | | |

Once the PBL-STEM-based student worksheet has been developed and confirmed, the next step is to conduct a practicality test. This will involve distributing questionnaires to Physics teachers and students to gather feedback on the use of PBL-STEM-based student worksheets as a learning medium. The recipient of this questionnaire was M. Istanto., a teacher at Muhammadiyah Kartosentanan Junior High School. The results of the Physics instructor's answers to the PBL-STEM-based student worksheet can be seen in Table 6.

Table 6. Analysis of Questionnaire Validation Test by Validator and Physics Teacher.

| Validator | Total Score | Maximum score | % | Category |
|---|---|---|---|---|
| M. Istanto | 15 | 15 | 100% | Very Practical |
| Kristina Uskenat | 14 | 15 | 93.3% | Very Practical |
| Don Jaya P | 14 | 15 | 93.3% | Very Practical |

Given the findings from the Physics teachers' answers, it is clear that the PBL-STEM-based student worksheets received a maximum score of 15 with a percentage of 100%. As a result, the student worksheets based on PBL-STEM is considered very practical. This conclusion is based on the questionnaire presented earlier.

Practical evaluation of the PBL-STEM-based student worksheets that will be used for research, was given to 20 students who completed the questionnaire response of this student. The responses of 20 students can be seen in Table 7.

Table 7. Analysis of Student Response Questionnaire Validation Test.

| N | Total Score | Maximum score | % | Category |
|---|---|---|---|---|
| 20 | 231 | 240 | 96% | Very Practical |

The table of student responses above shows that the student response to the PBL-STEM-based student worksheets used by 20 students reached a total score of 231 out of a maximum score of 240, with a percentage result of 96.22% in the category that is very practical to be used in learning activities. The Disseminate stage involves distributing or providing PBL-STEM-based student worksheets to students and evaluating the effectiveness of student worksheets. Furthermore, a direct trial on students at Muhammadiyah Kartosentanan Junior High School will be carried out to evaluate the effectiveness of the student worksheets. Efficiency results can be seen in Table 8.

Table 8. Effectiveness Test Analysis.

| N | Pre-test | Post-test | N-Gain | Category |
|---|---|---|---|---|
| 20 | 246 | 322 | 0,92 | High |

According to the data in the N-Gain table, the N-Gain score is 0.92 which falls into the high range. This study produced an average pre-test score of 12.3 and a post-test score of 16.1, indicating an increase in score of 3.8 from pre-test to post-test. The results of the analysis show that the PBL-STEM-based worksheets is considered very valid by Media Experts with a score of 96%. Material Experts also stated that it was very valid, with a score of 89.81%. In addition, Instrument Experts found that it was very valid, with a score of 95.45%. PBL-STEM-based worksheets in the practicality test are classified as Very Practical, as shown by Biology teachers and students who achieved scores of 100% and 96.22% respectively in this category. The PBL-STEM-based worksheets is very effective, as shown by the N-Gain value of 0.92 which falls into the high category. This shows that the use of PBL-STEM-based worksheets in learning leads to an increase in the level of creative thinking. The students' responses related to learning using PBL-STEM-based worksheets are presented in the following descriptive statistics table:

Table 9. Students' responses to learning using PBL-STEM-based student worksheets on temperature and heat material

| Category | Interval | Frequency | Percentage (%) | Mean | Median |
|---|---|---|---|---|---|
| Not Good | 14 – 24.5 | 2 | 10% | 40.5 | 41.0 |
| Quite Good | 24.6 - 35.0 | 4 | 20% | | |
| Good | 35.1 – 45.5 | 10 | 50% | | |
| Very Good | 45.6 – 56.0 | 4 | 20% | | |

Table 9 illustrates student responses to the PBL-STEM-based worksheets on temperature and heat, revealing that 70% of students rated their experience as either "Good" or "Very Good," indicating a largely positive reception. Specifically, 50% of students found the worksheets to be good, while 20% considered them very good. Conversely, 10% of students rated their experience as "Not Good," suggests a small portion found the worksheets unsatisfactory. Additionally, 20% of students deemed the worksheets "Quite Good," reflecting a moderately positive experience with some potential for improvement. Overall, the data suggests that while the PBL-STEM approach is effective for the majority, there are opportunities for refinement to address the needs of all students.

According to Choi et al. (2014), the Problem Based Learning paradigm can increase students' active participation in the learning process, resulting in higher knowledge accumulation and increased motivation to explore new information. The implementation of STEM approaches allows students to acquire knowledge through the process of exploring and conducting experiments to validate their assumptions (Sarican & Akgunduz, 2018). The PBL approach is integrated with STEM in worksheets

to facilitate meaningful learning by systematically combining information, concepts, and abilities. In a study conducted by Meityastuti & Wijaya (2022), it was found that the implementation of PBL-STEM-based student worksheets can improve students' creative thinking skills.

This research introduces a novel integration of Problem-Based Learning (PBL) with STEM methodologies through the development of Student Worksheets specifically tailored for teaching temperature and heat. The innovation lies in the systematic design and validation process of the PBL-STEM-based Student Worksheet, which includes rigorous expert validation across multiple dimensions of media, materials, and instruments. The research further distinguishes itself by providing a comprehensive analysis of the effectiveness of the Student Worksheets through pre-test and post-test comparisons, highlighting significant improvements in student performance and creative thinking. Additionally, the study integrates direct feedback from both educators and students, demonstrating the practical applicability and effectiveness of the PBL-STEM approach in a real classroom setting. The high validity scores and positive student responses underscore the contribution of this research to educational practices in physics.

The successful implementation and validation of the PBL-STEM-based Student Worksheet indicates its potential to enhance learning experiences in junior high school physics. The positive feedback from students and teachers suggests that this approach not only makes learning more engaging but also effectively improves students' understanding and application of complex concepts such as temperature and heat. Educators may consider adopting or adapting similar PBL-STEM-based materials to foster deeper learning and critical thinking skills. The study's limitations include its focus on a specific subject and school context, which may limit the generalizability of the findings to other educational settings and disciplines.

## CONCLUSION

This study successfully developed and implemented Student Worksheets based on Problem-Based Learning (PBL) and STEM for temperature and heat material at Muhammadiyah Kartosentanan Junior High School, which were considered very valid and practical by experts and users. The results showed a significant increase in students' understanding and creative thinking skills, with positive responses from most students. These findings indicate that PBL-STEM-based Student Worksheets are effective in increasing student engagement and understanding of physics concepts, although their application may need to be adjusted to other contexts and subjects.

## ACKNOWLEDGMENTS

Acknowledgments should be made only to those who have made a substantial contribution to the study. Authors are responsible for obtaining written permission from people acknowledged by name in case readers infer their endorsement of data and conclusions.

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