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Needs Analysis for the Development of STEM-Based Electronic Student Worksheets Oriented on Local Wisdom to Facilitate Problem-Solving Skills in the Topic of Temperature and Heat

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Abstract
Problem-solving skills are a 21st-century competency that students must possess in physics learning, but field observations indicate that achievement remains low. This study aims to analyze the need for developing STEM-based Electronic Student Worksheets oriented toward local wisdom to facilitate problem-solving skills in temperature and heat materials. Using the 4-D development model (Define, Design, Develop, Disseminate), this research focuses on the Define stage. Data were collected from 3 physics teachers and 34 students of grade XI F1 at SMAN 1 Linggo Sari Baganti using problem-solving ability tests, teacher interview guidelines, and student characteristics questionnaires. The results of the analysis showed that the average problem-solving ability of students is low at 52%, with achievement across five indicators as follows: useful description (52%), physics approach (53%), specific application of physics (49%), mathematical procedures (52%), and logical progression (54%). Furthermore, data revealed that 67.7% of students fall into the poor and very poor categories, while only 11.8% reach the very good category. Interview results confirmed that the teaching materials currently used are 100% conventional and have not yet integrated STEM approaches or local wisdom contexts. Questionnaire data indicated that while students demonstrate high readiness for technology-integrated learning, their current motivation is hindered by monotonous printed materials. This study concludes that there is an urgent need to develop interactive STEM-based Electronic Student Worksheets integrated with local wisdom to bridge the gap between physics theory and students' daily lives. The development of such innovative learning tools is essential to create more interactive, contextual, and effective learning environments that can significantly improve students' problem-solving skills.

INTRODUCTION

In the context of 21st-century education, physics learning is not only oriented toward the transfer of knowledge but also emphasizes the development of higher-order thinking skills (Sundari et al., 2024). These skills include critical thinking, creativity, collaboration, and especially problem-solving skills, which are essential competencies for students to face increasingly complex global challenges (Arisandi & Hidayati, 2024). In physics learning, problem-solving skills are not only related to the ability to perform mathematical calculations, but also involve the ability to understand phenomena, analyze problems, determine appropriate concepts, and evaluate solutions logically (Utami et al., 2024). Therefore, the development of problem-solving skills becomes one of the main objectives in physics education.

However, in practice, students' problem-solving abilities in physics are still relatively low. This condition is influenced by several factors. First, the learning process is still dominated by teacher-centered approaches such as lecture methods, which limit students' opportunities to actively engage in investigation and problem-solving activities (Afifah & Malik, 2025). Second, students tend to rely on memorizing formulas rather than understanding the underlying concepts, causing difficulties in applying knowledge to different problem situations Rosdiana; et al. (2024). Third, students often directly use mathematical equations without prior conceptual analysis, indicating weak conceptual understanding (Risamasu & Pieter, 2024). In addition, the limited availability of teaching materials that specifically facilitate higher-order thinking skills and problem-solving also contributes to this issue (Anwar, 2022). These conditions indicate that innovation in learning design and teaching materials is urgently needed.

In line with the implementation of the Independent Curriculum, learning is expected to be more student-centered, providing opportunities for exploration, critical reasoning, and contextual problem-solving (Rahmawati & Solihat, 2025). One of the innovations that can support this transformation is the development of electronic-based teaching materials, such as Electronic Student Worksheets. Electronic Student Worksheets offers various advantages compared to conventional worksheets, as it can integrate multimedia elements such as images, videos, animations, and interactive features that help students understand abstract physics concepts more effectively (Widodo et al., 2022). Through these features, Electronic Student Worksheets not only functions as a learning guide but also as an interactive learning medium that can increase student engagement and independent learning.

Furthermore, the integration of the STEM (Science, Technology, Engineering, and Mathematics) approach in Electronic Student Worksheets development is considered highly relevant in physics learning. The STEM approach facilitates the integration of scientific concepts with technological applications and engineering design processes, allowing students to solve real-world problems in a structured and meaningful way (Mauludyah, 2023). Through STEM-based learning, students are encouraged to actively construct knowledge, design solutions, test ideas, and reflect on the results obtained. This process is closely aligned with the development of problem-solving skills.

In addition to technological and pedagogical approaches, integrating local wisdom into physics learning is also an important aspect that should not be overlooked. Local wisdom can serve as a contextual bridge that connects abstract physics concepts with students' real-life experiences, making learning more meaningful and relevant (Setiani et al., 2022). By incorporating local wisdom, students are not only able to understand scientific concepts more deeply but also develop an appreciation for cultural values and local knowledge. This integration is particularly important in creating contextual and culturally responsive learning environments.

Several previous studies have demonstrated that STEM-based learning can improve students' higher-order thinking skills, including problem-solving abilities. Other studies have also developed Electronic Student Worksheets as an effective medium to enhance student engagement, independence, and conceptual understanding. In addition, research on the integration of local wisdom has shown that contextual learning can improve students' motivation and understanding of scientific concepts. However, these studies are generally conducted separately, focusing on only one aspect, such as STEM, Electronic Student Worksheets, or local wisdom. As a result, there is still a lack of comprehensive learning designs that integrate these three components simultaneously in a single instructional framework.

Moreover, studies that specifically focus on the development of STEM-based Electronic Student Worksheets integrated with local wisdom to facilitate students' problem-solving skills in temperature and heat materials are still limited. This indicates a clear research gap that needs to be addressed. Based on preliminary studies conducted at SMAN 1 Linggo Sari Baganti, students' problem-solving abilities in temperature and heat materials are still relatively low due to the use of conventional teaching materials that have not integrated innovative approaches . Therefore, this study aims to fill this gap by developing a STEM-based Electronic Student Worksheets oriented toward local wisdom to facilitate students' problem-solving skills in a more meaningful, contextual, and effective way.

METHOD

In its implementation, this study adopts a 4-D development model according to (Thiagarajan, 1974) which consists of four main stages, namely Define (Definition), Design (Planning), Develop (Development) and Disseminate (Spread). The 4D research method was chosen because the development process does not take long, considering that each stage is relatively simple and not too complex. This model is also suitable for developing instructional products systematically and effectively, as it offers a complete workflow from the identification of needs to the deployment stage so as to produce a quality and ready-to-use product. Then each stage is relevant to aspects of innovation development in the field of education, especially those related to the learning curriculum, education management, education policy and educational leadership (Waruwu, 2024).

The Define stage includes a needs analysis aimed at identifying problems in physics learning as the basis for developing teaching materials. This analysis was conducted at SMAN 1 Linggo Sari Baganti involving two research subjects, namely 3 physics teachers and 34 students of grade XI Phase F. Data from teachers were collected through interviews to obtain information regarding the learning process, teaching materials used, learning media, and learning models applied. Meanwhile, data from students were obtained through questionnaires and problem-solving ability tests to identify student characteristics and their level of problem-solving skills.

The instruments used in this study consist of interview guidelines, questionnaires, and problem-solving ability test sheets. Instrument validity was determined using expert validation (content validity) by involving experts in physics education and learning media. The validation results were analyzed using a Likert scale to determine the level of validity of each instrument before being used in the research.

The questionnaire used in this study was designed to analyze student characteristics and needs. The indicators in the questionnaire include: (1) students' interest in physics learning, (2) students' learning preferences, (3) the use of teaching materials, (4) students' difficulties in understanding temperature and heat concepts, and (5) students' experiences in solving physics problems. The questionnaire uses a Likert scale with several response categories to measure students' perceptions quantitatively.

Interview data obtained from teachers were analyzed using qualitative descriptive analysis techniques, which include data reduction, data presentation, and conclusion drawing. This analysis aims to describe the actual conditions of the learning process and identify problems faced by teachers in physics instruction. Meanwhile, questionnaire data were analyzed quantitatively by calculating the percentage of responses for each indicator and interpreting them based on predetermined criteria. The results of the problem-solving ability test were analyzed by calculating the average score and then categorized based on students' problem-solving ability levels.

Table 1. Assessment Criteria Problem-solving ability

Value Range	Category
81-100	Very good
66-80	Good
56-65	Pretty Good

41-55	Less
0-40	Fail

(Walidain et al., 2023)

RESULT AND DISCUSSION

Results

The results of the preliminary study were obtained through several data collection techniques, namely initial tests of problem-solving skills, analysis of student characteristics, and interviews with physics teachers at SMAN 1 Linggo Sari Baganti. The three techniques were used to obtain an initial overview of the conditions of physics learning in temperature and heat materials, both in terms of students' problem-solving skills, learning characteristics, and teaching materials used in the learning process. An initial test of problem-solving skills was given to 34 students of class XI F1 to measure their ability to solve physics problems based on five problem-solving indicators according to Docktor et al. (2016), namely Useful Description, Physics Approach, Specific Application of Physics, Mathematical Procedure, and Logical Progression. The results of the test were analyzed to determine the level of students' problem-solving skills and the difficulties that arise in each indicator. Furthermore, the results of the analysis are presented in Figure 1 as a basis for determining the need for the development of STEM-based electronic student worksheets oriented towards local wisdom. In addition, data on student characteristics and the results of interviews with teachers are used as supporting data to strengthen the initial findings, so that the basis for product development that is more in line with the needs of physics learning in schools is obtained.

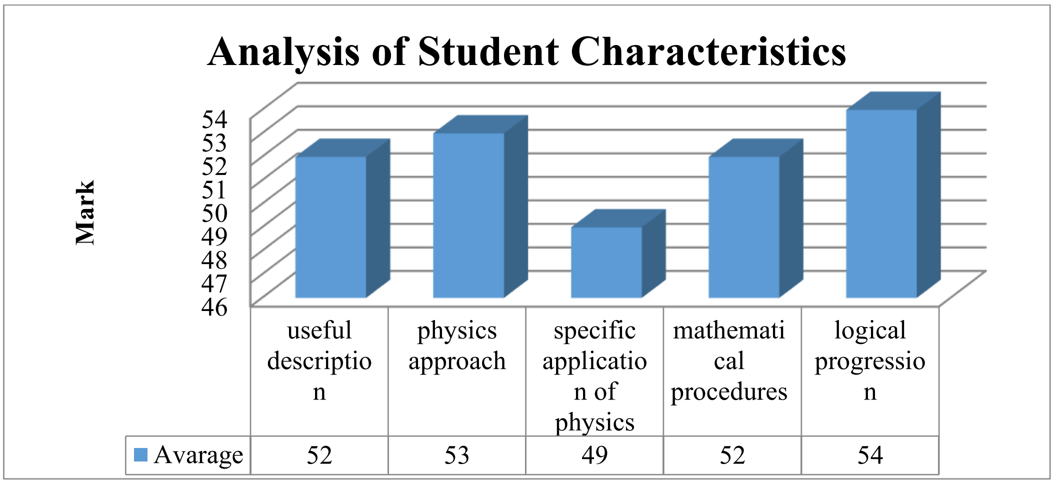

Figure 1. Problem-Solving Test Results

Based on Figure 1, the problem-solving ability indicators show a percentage that is still in the low category and has not reached the optimal level because there are no indicators in the high category. This finding indicates that students' problem-solving abilities have not developed adequately at each stage of problem solving. The Physics Concept Application indicator obtained the lowest percentage, at 49%, indicating that students still experience difficulties in connecting physics concepts to the context of the given problem. In fact, in physics learning, the ability to apply concepts is a crucial aspect because problem solving requires not only mastery of formulas, but also the ability to select and use concepts appropriately to explain phenomena scientifically. This low achievement indicates that students' understanding still tends to be procedural and have not yet achieved the ability to transfer concepts to new situations. Meanwhile, the Problem Description indicator obtained a percentage of 52%, indicating obstacles in identifying and formulating problems accurately, while the Logical

Reasoning indicator obtained the highest percentage, at 54%, but still does not demonstrate optimal reasoning abilities. In addition, of the total of 34 students, only 4 students (11.8%) were in the very good category, while the majority, namely 23 students (67.7%) were in the poor and failed categories, so a learning strategy is needed that is able to improve conceptual understanding and students' ability to apply physics concepts to problem solving contextually.

Table 2. Student Problem-Solving Test Results

Value Range	Category	Number of Students
81-100	Very good	4
66-80	Good	2
56-65	Pretty Good	5
41-55	Less	10
0-40	Fail	13

More deeply, the dominance of the category is lacking and fails to show that students are not able to carry out the stages of problem solving systematically, starting from describing problems, choosing the right physics approach, applying concepts to special situations, using mathematical procedures, to developing logical reasoning flows. The low number of students in the good and very good categories also indicates that high-level thinking skills, such as analysis, evaluation, and conceptual reasoning, have not been developed optimally. This condition shows that students still have difficulty in connecting the concepts of temperature and heat with the context of real problems, so that problem solving tends to be oriented towards the use of formulas procedurally. In addition, the low achievement in the category is quite good shows that students' basic understanding of temperature and heat materials is still limited. These findings indicate that there are other factors that also affect the low problem-solving skills of students. Therefore, to obtain a more comprehensive picture, further analysis of the characteristics of students and the results of interviews with physics teachers was carried out.

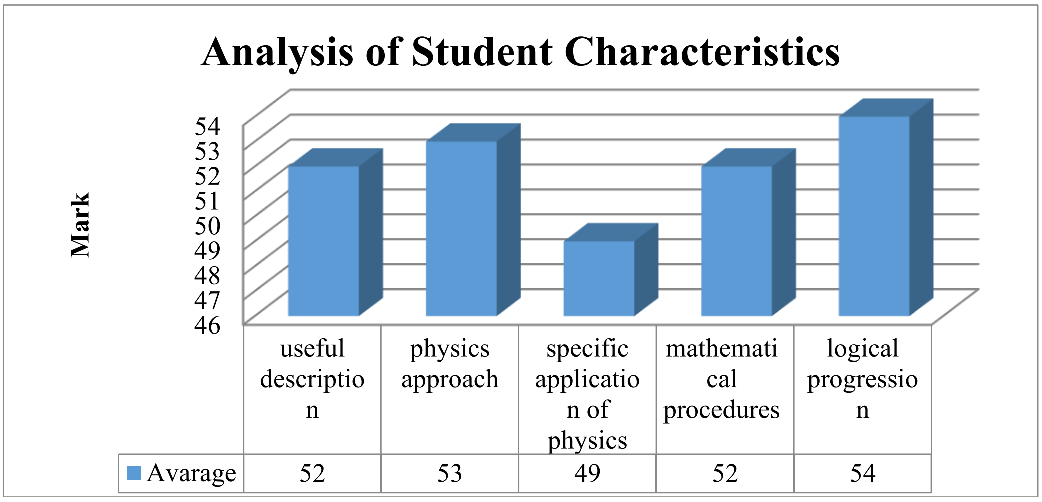

Figure 2. Analysis of Student Characteristics

Table 3. Summary of Student Characteristics Questionnaire Results

Aspect	Findings	Interpretation
Learning Interest	Students show interest in physics learning	Interest has not fully translated into active participation
Learning Style	Students tend to prefer visual and kinesthetic learning	Interactive and multimedia-based materials are needed

Learning Difficulties	Students experience difficulties understanding temperature and heat concepts	Students still struggle to connect formulas with physical meaning
Digital Habits	Students are familiar with digital devices	Students show readiness for technology-based learning
Supporting Facilities	Learning resources remain limited and conventional	Current teaching materials do not optimally support problem-solving

Based on Table 3 and Figure 2, students show positive interest in physics learning and readiness to engage in technology-based instruction. However, several challenges remain, particularly in understanding temperature and heat concepts and connecting formulas with physical meaning. Students also tend to prefer visual and kinesthetic learning, while existing teaching materials are still dominated by reading texts and routine exercises. In addition, limited learning resources reduce opportunities for investigation and active concept construction. These findings indicate the need for interactive and contextual digital teaching materials to support students' characteristics and facilitate problem-solving skills.

The results of interviews with physics teachers reinforced these findings. The teacher stated that physics learning has not been fully able to help students understand the material in depth due to the limited learning resources and teaching materials available. Teachers generally use student worksheet from MGMP, then modify it according to the needs of students. However, student worksheet that are available still tend to emphasize routine practice questions rather than scientific investigation activities. This condition lacks the support of active, contextual, and student-centered learning.

Furthermore, students still have difficulties in carrying out the systematic problem-solving stages. They are not used to describing problems, determining the right approach to physics, applying concepts to specific situations, using mathematical procedures correctly, and devising logical lines of reasoning. This problem shows that the learning that takes place has not fully trained the problem-solving indicators as used in this study, namely Useful Description, Physics Approach, Specific Application of Physics, Mathematical Procedure, and Logical Progression.

Based on the overall findings, it can be concluded that the problems of physics learning on temperature and heat materials are complex. The problem does not only lie in the low problem-solving skills of students, but also related to teaching materials, learning strategies, media, and limited learning resources. Therefore, it is necessary to innovate teaching materials in the form of electronic student worksheet STEM-based and oriented to local wisdom. Electronic student worksheet It is expected to be able to integrate the concepts of physics, technology, engineering, mathematics, and local cultural contexts in a series of interactive, contextual, and meaningful learning activities for students.

Discussion

The results of the preliminary study indicate that students' problem-solving abilities in the topic of temperature and heat are still in the low category with an average initial test score of 52%. This finding indicates that students have not been able to carry out the complete physics problem-solving process, which includes understanding the problem, selecting relevant concepts, applying concepts to specific situations, using mathematical procedures, and constructing logistical reasoning. This achievement indicates that the obstacles experienced by students do not only occur at the stage of obtaining answers, but also throughout the problem-solving process. This finding is in line with Docktor et al. (2016) who stated that physics problem-solving abilities need to be explained based on the thought process at each stage of the solution. Thus, the low results obtained reflect the students' less than optimal ability to develop a comprehensive problem-solving strategy.

This low ability is thought to be influenced not only by limited mathematical abilities but also by the underdevelopment of integrated conceptual understanding. Docktor et al. (2016) explained that novice problem solvers tend to use formula matching strategies, while expert problem solvers construct solutions based on relationships between physics concepts. This condition explains why students tend to be able to memorize equations but experience difficulties when having to explain the physical meaning and apply it to temperature and heat phenomena. These difficulties indicate that the learning process has not fully encouraged the transfer of concepts from theoretical knowledge to contextual application. As a result, students experience obstacles when facing problems that require reasoning and conceptual interpretation.

The characteristics of temperature and heat materials are also factors that can explain students' low problem-solving abilities. This material is abstract because it involves the relationship between real phenomena, visual representations, scientific concepts, and mathematical models simultaneously. Concepts such as heat transfer and temperature change require students to understand cause-and-effect relationships that cannot be directly observed. If these relationships are not established through appropriate learning experiences, students tend to use formulas without understanding their physical meaning. This condition makes the concepts difficult to apply to different problem contexts.

The interview results show that the teaching materials used are still dominated by reading and routine exercises so that students' opportunities to carry out investigations and develop concepts independently are still limited. This condition shows that there is a gap between the principles of meaningful learning and the learning practices that take place in the classroom. Learning that is oriented towards procedural solutions can reduce students' opportunities to develop conceptual reasoning. In fact, problem solving abilities develop when students are involved in exploration and reflection activities on physical phenomena. Therefore, a more contextual learning approach is needed to support concept understanding.

Compared with previous research, the results of this study reinforce the finding that physics learning that overemphasizes mathematical procedures without conceptual exploration tends to result in low problem-solving abilities. However, this study shows that the causes of this low ability are not only related to conceptual aspects, but are also influenced by the characteristics of the teaching materials used. Thus, this study extends previous findings by demonstrating that learning design also plays a role in shaping students' problem-solving abilities. These findings provide the perspective that improving problem-solving abilities requires support from an appropriate learning environment. Therefore, learning interventions need to consider more than one factor.

Analysis of student characteristics indicates that students have visual and kinesthetic learning tendencies and are prepared to use technology in their learning. These findings suggest that low problem-solving skills are not always related to low learning interest. Instead, this condition can be influenced by a mismatch between student learning characteristics and the available learning materials. When students' learning needs are not met, the concept-building process is less than optimal. Therefore, adjusting learning strategies is crucial for improving problem-solving skills.

These findings strengthen the reasons why the use of electronic student worksheets is relevant to develop. Electronic student worksheets allow for the integration of multimedia, simulations, videos, and interactive activities that can help visualize temperature and heat concepts. The use of digital media also provides students with the opportunity to learn more actively and flexibly. This finding is in line with research by Hanum and Asrizal (2023) which shows that well-designed physics teaching materials can improve students' problem-solving and creative thinking abilities. However, this research adds that the effectiveness of teaching materials is also influenced by their suitability to students' learning characteristics.

The STEM approach in this study was used as a strategy to help students develop more systematic thinking processes. In theory, STEM integrates science, technology, engineering, and mathematics in the context of solving real-world problems. Azizah and Setyawarno (2025) showed that the STEM approach can improve students' computational thinking and problem-solving skills. Unlike previous research, this study places STEM within the structure of electronic student worksheets that are explicitly linked to indicators of problem-solving ability. Thus, STEM functions not only as a learning approach but also as a framework for developing thinking skills.

The integration of local wisdom is another distinguishing feature emerging from this research. Setiani et al. (2022) explain that local wisdom can serve as a conceptual bridge to understanding abstract physics phenomena. In this study, local wisdom is not merely used as additional context but is positioned as a trigger for learning problems. This approach allows students to connect the concepts of temperature and heat to experiences close to their lives. This is expected to help students develop a more meaningful understanding.

The contribution of this research lies in the integration of electronic student worksheets, the STEM approach, local wisdom, and problem-solving ability indicators into a single learning design. Unlike previous research that tended to develop each aspect separately, this study demonstrates that integration between components is necessary to address low problem-solving abilities in temperature and heat. These findings broaden the understanding that developing teaching materials cannot simply focus on media digitization. Thus, the developed teaching materials are expected to support more contextual, systematic, and thought-oriented learning. This research also provides an empirical basis for developing physics teaching materials that better suit the needs of 21st-century learning.

CONCLUSION

Based on the results of the preliminary study, it can be concluded that students' problem-solving skills in temperature and heat materials are still relatively low and have not developed optimally. This can be seen from students' difficulties in describing problems, determining appropriate physics approaches, applying concepts to specific situations, using mathematical procedures, and constructing logical reasoning. This condition is influenced by the limitations of the teaching materials used, learning processes that are not fully student-centered, and the lack of activities that encourage independent exploration, investigation, and knowledge construction. In addition, the abstract nature of temperature and heat materials, which are closely related to mathematical calculations, further strengthens the obstacles faced by students in understanding and applying physics concepts to real-world problems.

On the other hand, the results of the analysis of student characteristics indicate that students have an interest in learning, tend to prefer visual and kinesthetic learning styles, and are ready to utilize technology as a learning medium. However, this potential has not been fully supported by the availability of digital teaching materials that are interactive, contextual, and aligned with students' learning needs. Therefore, the development of STEM-based Electronic Student Worksheets oriented toward local wisdom is considered a relevant solution. Such teaching materials have the potential to help students understand temperature and heat concepts more concretely through local cultural contexts, facilitate technology-based learning, and train problem-solving skills in a systematic and meaningful way.

The implications of this study indicate that the development of STEM-based E-LKPD integrated with local wisdom can serve as an innovative instructional solution to improve students' problem-solving skills in physics learning. This study contributes to the development of more contextual, student-centered, and technology-integrated learning designs, particularly in temperature and heat materials. In addition, this research supports the implementation of the Independent Curriculum by providing teaching materials that encourage active learning, critical thinking, and real-world problem-solving.

Furthermore, this study also has practical implications for teachers, as it provides a reference for designing and implementing digital teaching materials that are aligned with students' characteristics and learning needs. For schools, this development can support the integration of local wisdom and technology in learning, thereby enhancing the quality and relevance of education.

For future research, it is recommended to conduct further studies on the implementation and effectiveness of STEM-based E-LKPD oriented toward local wisdom in different schools and learning contexts. In addition, future studies can explore the impact of this teaching material on other higher-order thinking skills, such as critical thinking and creativity. Researchers are also encouraged to integrate more advanced technologies, such as simulations or virtual laboratories, to enhance interactivity and learning outcomes. Finally, further development can be carried out on different physics topics to expand the applicability of this learning innovation.

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