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Effectiveness of Electronic Student Worksheet using Problem Based Learning Model on Heat and Heat Transfer Material on the Learning Outcomes of Grade XI Students

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ABSTRACT

In the current era of digital transformation in education, the quality and variety of learning resources play a crucial role in fostering meaningful learning experiences. However, how student learning outcomes remain a critical issue at MAN Kota Solok, particularly due to the limited variety and lack of attractiveness of the teaching materials currently used. This problem underscores the urgency of developing innovative learning resources that can increase student engagement and conceptual understanding. As a solution, this study implements an Electronic Student Worksheet based on the Problem-Based Learning model, which is designed to make learning more interactive and meaningful. The purpose of this study was to determine the effectiveness of the PBL-based Electronic Student Worksheet in improving student learning outcomes. This research employed a quasi-experimental design with a Posttest-Only Control Design, involving two groups: an experimental group using the PBL-based Electronic Student Worksheet and a control group using the conventional worksheets provided by the school. Data were collected through cognitive posttests and psychomotor assessments during the learning process. The findings revealed that the experimental group achieved higher average scores in both cognitive and psychomotor domains than the control group. Furthermore, hypothesis testing showed that the calculated t-value exceeded the critical t-value, indicating a significant difference between the two groups. These results demonstrate that implementing the PBL-based Electronic Student Worksheet effectively enhances student learning outcomes. This study contributes to the development of innovative digital learning resources that not only foster active student participation but also promote deeper conceptual understanding.

INTRODUCTION

Education serves as a fundamental pillar in shaping individuals who are capable of competing effectively in the global arena. Its purpose goes beyond merely increasing knowledge and skills; it also aims to develop students character to be critical, creative, and adaptive to the demands of the times (Asrori, 2020). In the era of rapid technological advancement, education systems are challenged to produce graduates who are not only

academically competent but also possess problem-solving and collaborative abilities (Susanto & Hapudin, 2024). Therefore, educational innovations are urgently needed to ensure learning processes remain relevant and responsive to societal changes (Kovalchuk et al., 2022). By integrating character education with modern pedagogical approaches, schools can better prepare students to face the dynamic challenges of the 21st century (Iksal et al., 2024).

The quality of the instructional process plays a crucial role in determining the success of education, as it involves meaningful interactions between educators and learners, encompassing knowledge, attitudes, and skills (Darling-Hammond et al., 2020). High-quality instructional practices foster active participation, critical thinking, and the development of both cognitive and socio-emotional competencies among students. In this context, the Merdeka Curriculum implemented in Indonesia represents an innovative educational policy designed to provide educators with greater flexibility to create active, interactive, and engaging learning experiences tailored to the unique characteristics of learners (Kemendikbud, 2022). Such flexibility enables educators to integrate student-centered approaches and adapt teaching strategies to meet diverse learning needs, ultimately enhancing educational outcomes (Tang, 2023).

The independent curriculum gives educators the freedom to design active, creative, and enjoyable learning processes that encourage optimal student engagement. Learning in this curriculum is student-centered, requiring students to take an active role in constructing their own knowledge through exploration, discussion, and problem solving (Sugrah, 2020). In this context, teachers act as facilitators who guide students in connecting theoretical concepts with real-life applications, fostering deeper understanding (Pebrianti & Irawati, 2024). The effectiveness of such learning processes greatly depends on the availability of relevant and contextual teaching materials that support independent and critical thinking (Utia et al., 2024). Thus, the success of this type of learning process is highly dependent on the availability of relevant teaching materials that can be used in learning to improve student learning outcomes.

However, the actual conditions found in the field are not yet in line with the ideal conditions. The first actual condition is that the implementation of the learning model is not yet in line with the syntax of the learning model and the learning process is still teacher-centered. Teacher-dominated learning tends to make students feel bored because the learning is too monotonous and they find the lessons difficult, which ultimately results in low learning outcomes for students (Precious, 2020). The second real condition is that the teaching materials used are not very interesting because they only present text and images, without any interactive elements. More effective and interactive teaching materials can improve students understanding and learning outcomes at school (Anabel & Emilliannur, 2024). Teaching materials significantly influence student learning outcomes, particularly in physics education (Miftahurrahmi et al., 2021; Asrizal et al., 2023). Based on the issues outlined, innovation in teaching is necessary. One solution that can be offered is the use of interactive teaching materials and innovative teaching models.

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Teaching materials significantly influence student learning outcomes, particularly in physics education (Miftahurrahmi et al., 2021; Asrizal et al., 2023).

Based on the issues outlined, innovation in teaching is necessary. One solution that can be offered is the use of interactive teaching materials. Teaching materials in the independent curriculum are an important component that supports the learning process so that it can run well. Teaching materials do not only include printed textbooks, but can also be in the form of electronic modules, videos, and electronic worksheets (Kemendikbud, 2024). In creating interactive learning, teaching materials can be developed by utilizing technological developments. Innovations in teaching materials with technological developments have transformed printed teaching materials into electronic teaching materials. Integrating technology into education serves as a strategic approach to fulfilling the need for effective teaching materials, enabling students to reach their maximum learning potential. Interactive instructional resources can significantly enhance students comprehension and academic performance in school (Anabel & Emilliannur, 2024). Instructional materials play a crucial role in shaping student outcomes, with a notable influence in physics education (Miftahurrahmi et al., 2021; Asrizal et al., 2023). Teaching materials must be designed to attract students attention, present information systematically, and be relevant to students needs in order to improve learning outcomes. The application of engaging instructional materials can be achieved by utilizing technology in learning. One illustration of employing technology in teaching is the adoption of Electronic Student Worksheets.

Electronic Student Worksheet is a worksheet presented in electronic form. The advantages of Electronic Student Worksheet include the use of interactive features such as videos, animations, quizzes, and simulations, enabling Electronic Student Worksheet to engage and enhance student participation in the course of learning (Siregar et al., 2024). In addition, Electronic Student Worksheet can be accessed via digital devices anytime and anywhere, facilitating the process of student learning both inside and outside the classroom (Firtsanianta & Khofifah, 2022). In addition to the application of innovative teaching materials, the learning process is more optimal when integrating innovative learning models into Electronic Student Worksheet.

The integration of these learning models aims to make the learning process more focused and in line with the syntax of the learning model. Some innovative learning models include Problem-Based Learning (PBL), Project-Based Learning (PjBL), Discovery Learning, and Inquiry Learning. These learning models are intended to student engagement to take increased participation throughout the learning process. One learning model that can increase student engagement in the learning process is PBL. The PBL models supports student-centered learning by stimulating active involvement throughout the learning process. The PBL model actively involves students in solving problems through the stages of the scientific method (Ardianti et al., 2021). The structured stages of the PBL learning model, which includes introducing problems to students, preparing the learning environment, directing individual or collaborative inquiries, developing and producing works, and assessing and evaluating the process of problem solving, can encourage student participation and foster the development of students thinking skills (Arends, 2012). The PBL model helps enhance students abilities in solving problems (Hidayati et al., 2023; Desnita et al., 2024; Asrizal et al., 2023). PBL can also improve students physics learning outcomes because this model can be used for experiment-based and simulation-based learning in accordance with the characteristics of physics material so that students can see natural phenomena that occur in everyday life (Desnita et al., 2021; Paradina et al., 2019).

Previous research has successfully developed valid and practical electronic student worksheets based on the Problem-Based Learning model (Nursipa et al., 2024). However, its

effectiveness in improving student learning outcomes has not yet been evaluated. This study aims to investigate the effectiveness of implementing the PBL-based electronic student worksheet in enhancing the learning outcomes of grade XI students at MAN Kota Solok. Specifically, it focuses on the topic of heat and heat transfer, where the E-worksheet is expected to foster active learning and deeper conceptual understanding. The findings of this research are anticipated to provide empirical evidence of the impact of PBL-based E-worksheets on student achievement and contribute to the development of more effective digital learning tools.

METHODS

This research adopts a quantitative approach with a quasi-experimental method, utilizing a Posttest-Only Control Group Design. The study was conducted at MAN Kota Solok during the second semester of the 2024/2025 academic year. The research population are students enrolled in class XI Phase F at MAN Kota Solok. The research sample comprises two classes: an experimental class and a control class. The sampling technique used is a saturated sample technique. The research subjects numbered 66 students, with 34 students assigned to the experimental class, while 32 were placed in the control class.

The study procedure followed the following steps: preparation, implementation, and completion. Activities conducted during the preparation stage included determining the location and schedule for the research, obtaining research permits, determining the sample, and preparing learning materials and research instruments. In addition, we also conduct trial questions, analyze the results of the trial questions, and take posttest question items. The implementation stage involved conducting learning activities in the sample classes. Learning in the experimental class was conducted using an Electronic Student Worksheet with the PBL model, while the control class used printed Student Worksheet. The two sample classes applied an identical instructional model, namely Problem Based Learning (PBL). In the final stage, the learning outcomes in terms of knowledge were assessed.

The instrument used was a written test that had undergone validity, reliability, difficulty level, and discriminating power tests. Meanwhile, the psychomotor aspect was assessed in the course of learning. The instrument used was a scoring rubric in the format of practical performance assessment. These instruments were carefully designed to obtain comprehensive and accurate data relevant to the study objectives.

The data analysis method applied to assess learning outcomes in the knowledge and psychomotor domains involved converting scores into values, followed by statistical testing to test the hypothesis. Before proceeding with hypothesis testing, the data undergo a normality test to confirm whether they are normally distributed or not (Sudjana, 2002). After that, the homogeneity of the data was tested using the F-test to see whether the two samples had homogeneous variances or not. If the data met the assumptions of normality and homogeneity, hypothesis testing proceeded with a t-test to analyze if a significant difference was present in the learning outcomes of students from both the experimental and control groups (Sugiyono, 2017). The obtained t-value is compared to the critical value in the t-table at a 5% significance level. If the calculated t-value exceeds the t-table value, H_0 was rejected while H_1 was accepted, suggesting that significant difference exists between the two samples.

RESULTS AND DISCUSSION

Results

Knowledge Aspect Learning Outcomes

After implementing the Electronic Student Worksheets based on the Problem-Based Learning model for the topics of heat and heat transfer, a posttest was administered to the students to assess their learning outcomes. This posttest was designed to evaluate the extent of students understanding of the concepts learned through the application of this model. The posttest data was then analyzed using appropriate statistical techniques to obtain an accurate picture of the effectiveness of using Electronic Student Worksheets. The results of the analysis of the students posttest data can be seen in Table 1.

Table 1. Analysis of Students Knowledge Aspects

Statistical Parameters	Experiment Group	Control Group
Average value	84	76
Standard deviation	12.16	9.70
Variance	147.88	94.06
Maximum value	100	92
Minimum value	67	50
Range	33	42
Lo value test for normality	0.143	0.149
Lt value test for normality	0.152	0.156
Fh value for homogeneity test	1.572	
Ft value for homogeneity test	1.799	
t-test value	2.56	
t-table value	1.99	

The first analysis result relates to the impact of the Electronic Student Worksheet for PBL model on knowledge aspects. The purpose of this analysis is to investigate the impact of the Electronic Student Worksheet for PBL model on two sample groups in terms of knowledge aspects. The differences in the mean values and standard deviations were calculated using data on students knowledge aspects from two groups: the experimental group, which used the Problem-Based Learning (PBL) Electronic Student Worksheet, and the control group, which did not use it. A summary of the analysis comparing students knowledge aspects in the experimental and control groups is presented in Table 1. Based on the data in Table 1, a clear difference can be observed in the knowledge scores between the two groups. The average scores for the experimental and control classes were 84 and 76, respectively, indicating a variation in students knowledge aspect scores between the groups. However, this difference alone does not confirm a significant effect of the PBL-based Electronic Student Worksheet on students knowledge aspects. To verify this, a two-independent-sample t-test was conducted after performing prerequisite tests. Normality testing results showed that L0 < Lt, indicating that the students knowledge aspect scores in both groups were drawn from a normally distributed population. Furthermore, the homogeneity test revealed Fh < Ft, which indicates that the variances of the two groups were homogeneous. Given that the data were

normally distributed and homogeneous, a two-independent-sample t-test was appropriate for hypothesis testing. The results of this analysis demonstrated that the obtained value fell outside the acceptance region of the null hypothesis. The results show that the application of Problem-Based Learning (PBL) positively affects student learning outcomes in the subjects of heat and heat transfer in terms of knowledge.

Psychomotor Aspect Learning Outcomes

The psychomotor aspect was assessed during the practical activities. Students psychomotor skills were measured each time they conducted practical activities, which took place over four sessions. There were five indicators of students practical skills that were assessed during the learning process. The five indicators were observing (M1), asking questions (M2), gathering information (M3), reasoning (M4), and communicating (M5). Results of the data plot from the indicators of students practical skills is shown in Figure 1.

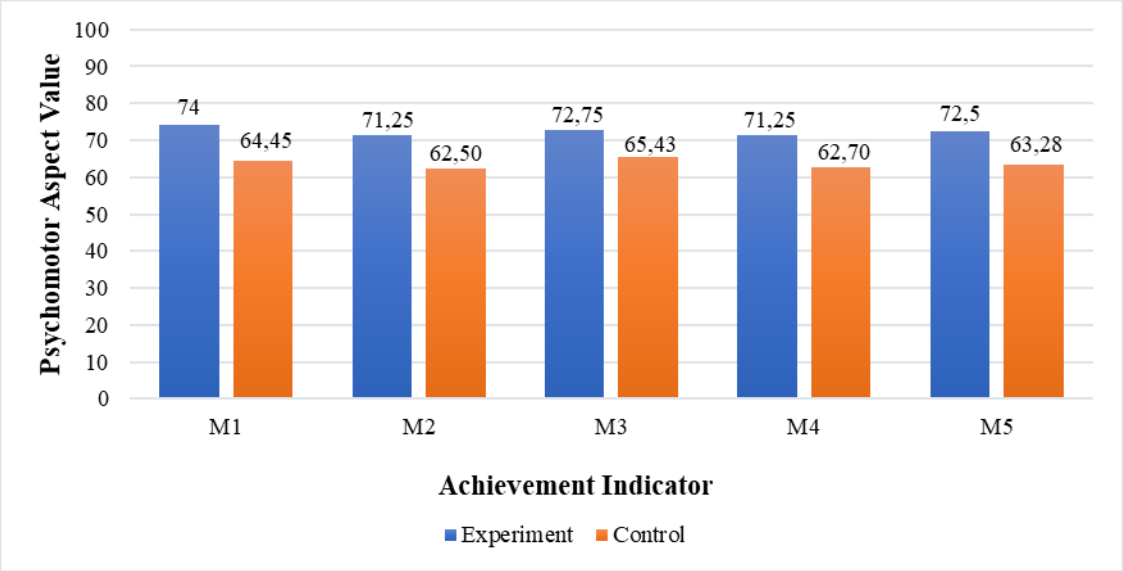

Figure 1. Learning Outcomes in Psychomotor Aspects

The data presented in Figure 2 illustrates the average scores for each psychomotor assessment indicator in the experimental and control groups. The analysis shows that the experimental group consistently achieved higher scores across all indicators. These results demonstrate a noticeable difference in psychomotor performance between the two groups. This difference reflects the impact of using the PBL-based Electronic Student Worksheet in the experimental group compared to the control group that did not use it.

The second analysis result is related to the impact of the Electronic Student Worksheet for PBL model on psychomotor aspects. The aim of this study is to examine the effect of the Problem-Based Learning (PBL) Electronic Student Worksheet on the psychomotor skills of two distinct sample groups. Variations in the mean scores and standard deviations were analyzed based on psychomotor data from students in the experimental group, who utilized the PBL-based Electronic Student Worksheet, and the control group, who did not. A summary of the comparative analysis of psychomotor performance between the experimental and control groups is presented in Table 2.

Table 2. Analysis of Students Psychomotor Aspects

Statistical Parameters	Experiment Group	Control Group
Average value	72.35	63.67
Standard deviation	8.59	10,58
Variance	73.79	111.93
Lo value test for normality	0.100	0.126
Lt value test for normality	0.152	0.156
Fh value for homogeneity test	1.516	
Ft value for homogeneity test	1.799	
t-test value	2.99	
t-table value	1.99	

Based on the data presented in Table 2, there is a noticeable difference in the psychomotor scores between the experimental and control groups. The mean scores for the two classes are 72.35 and 63.67, respectively, indicating a variation in students psychomotor performance across the groups. However, this difference alone does not yet confirm a significant effect of the Problem-Based Learning (PBL) Electronic Student Worksheet on students psychomotor skills. Therefore, a two-independent-sample t-test was conducted after performing normality and homogeneity checks. The normality test results showed that L0 < Lt, indicating that the psychomotor data from both groups are normally distributed. Similarly, the homogeneity test results revealed that Fh < Ft, which confirms that the variances between the two groups are homogeneous. Since the data meet these assumptions, a two-independent-sample t-test was applied to test the hypothesis. The results showed that the obtained t-value lies outside the acceptance region for the null hypothesis, implying a significant difference between the groups. Consequently, H1 is accepted, confirming that the use of the PBL-based Electronic Student Worksheet has a significant positive effect on students psychomotor learning outcomes in the topic of heat and heat transfer.

Discussion

The data obtained indicate that the PB based Electronic Student Worksheet model for heat and heat transfer material has a positive effect concerning the learning outcomes of grade XI students at MAN Kota Solok. Cognitive learning outcomes demonstrate that the average posttest scores of students in the experimental group employing the PBL-based Electronic Student Worksheet model surpass those recorded by the control group using Student Worksheet at school. Learning with the Electronic Student Worksheet PBL model helps students understand physics concepts in depth through problem-solving processes. This aligns with the research by Armanda & Putra (2023), which indicates that the implementation of the Electronic Student Worksheet with PBL model influences students competency achievement. The improvement in learning outcomes indicates that the implementation of PBL not only sharpens critical thinking skills but also enhances students conceptual understanding. This finding aligns with Amirulloh et al (2025) who state that students understand the concepts taught better because they discover them through direct observation, exploration, and individual experience. Oktaweri & Festiyed (2020) which indicates that the PBL model can be one of the most engaging learning models to use in education. Through the PBL model,

students become more enthusiastic about learning, whether in the presence of a teacher or outside of school hours without teacher supervision, as the PBL model has a structured syntax that can enhance students knowledge competencies.

In addition to assessing knowledge aspects, psychomotor aspects were also evaluated. Psychomotor assessment was conducted by observing students practical skills during each session, covering five skill indicators: conducting observations, posing questions, collecting data, analyzing, and sharing findings. The findings on psychomotor learning showed that the experimental group was higher than the control group in terms of average scores. Research by Risma & Yanti (2020) also indicates that the PBL model is capable of enhancing student learning outcomes. This improvement is due to the characteristics of PBL based learning, which demands students active participation during the learning process, especially in practical activities and problem solving that involve observation, critical thinking, and scientific communication skills. During practical activities, students are more active in answering questions in the PBL based Electronic Student Worksheet, thereby encouraging group collaboration. This aligns with the findings of Robbani (2024) that PBL creates a learning environment that requires students to identify problems, gather information, and formulate solutions both independently and in groups.

The PBL model is able to facilitate learner-centered learning that encourages them to be active in the learning process. These results are in line with previous research stating that the PBL model actively involves learners in solving problems through the stages of the scientific method (Ardianti et al., 2021). Electronic Student Worksheet is presented in combination with engaging instructional videos and practical activities, and applies organized steps within every aspect of the learning process. The implementation of the Electronic Student Worksheet, equipped with interactive features, facilitates students in accessing, comprehending, and actively utilizing the material (Lathifah et al., 2021).

CONCLUSION

The conclusion of this study was drawn based on the data analysis conducted. The implementation of Electronic Student Worksheets using the Problem Based Learning (PBL) model proved effective in improving students learning outcomes in both cognitive and psychomotor aspects. These findings indicate that the the Electronic Student Worksheet for PBL model can increase students enthusiasm for learning while enhancing their conceptual understanding and psychomotor skills. In addition, the use of the Electronic Student Worksheet for PBL model supports teachers in conducting more structured, efficient, and engaging learning processes. Therefore, it is recommended for physics teachers to apply the the Electronic Student Worksheet for PBL model in their teaching to improve student learning outcomes. Thus, the the Electronic Student Worksheet for PBL model can serve as an effective learning innovation to achieve educational goals in schools.

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