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DESIGN OF ELECTRONIC LKPD WITH INTEGRATED STEM PBL MODEL ON HEAT MATERIAL

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ABSTRACT

The low level of students' problem solving skills in physics, especially in heat, is strongly suspected to be related to the unoptimal learning model and the limited variety of teaching resources, where teachers still rely heavily on print-based materials that are less interactive. As a solution, this research aims to develop Didik electronic LKPD based on PBL model integrated with STEM approach for heat topic. This development research uses the Plomp model, with a reporting focus on the one-to-one and small group feasibility test stages. Data obtained from validation sheets and practicality questionnaires were analyzed using score techniques, V Aiken, and percentages. The results of expert validation resulted in a score of 0.95 very valid, while the practicality test obtained a score of 86.41% in the one-to-one stage and 87.79% in the small group stage, both of which were classified as very practical. These findings prove that the developed PBL-STEM electronic LKPD product is feasible and ready to be tested further to measure its effectiveness in improving students' problem solving skills.

Keywords: Electronic LKPD, Problem Based Learning, STEM, Heat, Problem Solving Skills.

I. INTRODUCTION

The 21st century is characterized by the rapid development of technology and science that requires the world of education to adapt in preparing human resources that are able to compete globally. In the context of a knowledge-based society, mastery of 21st century skills is an urgent need which includes critical thinking, problem solving, communication, creativity, and collaboration [1]. Among these skills, problem solving occupies a critical position because it is multidimensional and integrates all 21st century skill domains, functioning as a nexus that connects critical thinking, creativity, collaboration, and communication in an authentic context [2]. This ability is a high-level thinking competency that requires the integration of knowledge structures with applicative skills [3]. Problem solving in science requires not only conceptual understanding but also epistemic ability to evaluate evidence and build scientific arguments [4]. In the field of science and technology, this ability requires students not only to master theoretical concepts but also to be able to apply them procedurally to solve real-life problems, through processes such as identifying the root of the problem, analyzing information, and evaluating the resulting solution [5].

In response to the demands of developing 21st century skills, the Indonesian government implemented the Merdeka Curriculum which is designed to support the strengthening of learners' problem-solving abilities. This curriculum provides flexibility for teachers in choosing appropriate teaching models and materials, including inquiry-oriented learning models such as Problem Based Learning (PBL), Project Based Learning (PjBL), and Discovery Learning [6]. However, the implementation of this curriculum still faces real challenges, especially in physics learning. Initial findings at SMA Negeri 1 Bonjol revealed that students' problem solving skills in heat were still relatively low, with students having difficulty in applying the stages of problem solving starting from problem identification, problem formulation in physics concepts, solution planning, to evaluation of results as revealed from interviews with physics subject teachers. This condition is consistent with the findings of international assessments that place Indonesia at the bottom of the rankings in problem solving skills based on the results of PISA and TIMSS [4]. This fact reinforces the urgency of developing learning innovations that not only focus on concept mastery, but also train students in solving problems authentically, especially on abstract concepts such as heat processes that require visualization and procedural applications.

In this context, the Problem Based Learning (PBL) model offers a relevant solution to overcome this gap. As a problem-centered learning model, PBL is specifically designed to develop students' problem-solving skills through the submission of contextual problems that encourage students to be actively involved in finding relevant information and constructing their own knowledge [7]. In its implementation, the teacher acts as a facilitator who presents real problems, so that students not only hone their high-level thinking skills but also foster a sense of responsibility and curiosity about the learning material [8]. This approach directly addresses the difficulties of students at SMA Negeri 1 Bonjol, for example by facilitating the formulation of physics problems through daily life scenarios, which conventional methods often fail to address. With these characteristics, PBL is a strategic choice for physics learning, especially in heat where students need to connect theory with practical applications.

To optimize the effectiveness of PBL, integration with the STEM (Science, Technology, Engineering, Mathematics) approach can be a powerful strategy, as STEM offers a holistic framework that allows students to solve problems through the integration of interrelated disciplines [9,10]. In physics learning, PBL-STEM integration guides students not only to understand science concepts theoretically, but also to apply them in engineering design by considering technological aspects and mathematical analysis such as designing heat simulation models involving mathematical calculations and engineering prototypes. Through this integrated approach, students experience a more authentic and contextualized problem-solving process, which specifically addresses students' procedural weaknesses by encouraging interdisciplinary collaboration and a comprehensive understanding of the real-life applications of science. This integration is also aligned with the Merdeka Curriculum, which emphasizes authentic project-based learning to build 21st century competencies.

The implementation of STEM-integrated PBL requires adequate teaching materials as a support system so that learning procedures can be carried out properly, one of which is through Electronic Learner Worksheets (E-LKPD). In contrast to conventional LKPD, E-LKPD offers higher flexibility and interactivity through the integration of multimedia and digital features, which allows visualization of abstract concepts dynamically [11]. Based on the results of interviews with physics teachers at SMA Negeri 1 Bonjol, information was obtained that the teaching materials currently used, namely printed books and conventional LKPDs, have minimal structured guidance and limitations in visualizing abstract concepts such as the heat process, which causes learning implementation to be less effective and students' problem solving skills do not develop procedurally. These findings indicate that conventional teaching materials fail to provide the gradual scaffolding and immediate feedback needed to overcome students' difficulties in applying the stages of problem solving for example, students have difficulty formulating physics problems due to the lack of visual examples, so that the learning process becomes undirected and less stimulating learning motivation. Therefore, the selection of PBL-based E-LKPD integrated with STEM is the main basis for replacing existing teaching materials, because this E-LKPD is specifically designed to integrate elements of science, technology, engineering, and mathematics through authentic activities such as identification of real problems, hypotheses, simulation experiments, and evaluations that provide systematic guidance, visual interactivity, and adaptive flexibility to build students' KPM holistically and gradually. Thus, this E-LKPD directly addresses the interview findings by providing the missing procedural support, ensuring effective implementation of PBL-STEM in developing students' procedural competencies [11]; 12].

This study has a different position in the map of NPD development for problem solving skills. Some previous studies [7]; [13] developed LKPDs with separate approaches, some only used the PBL model without STEM integration, or conversely applied the STEM approach without a systematic PBL framework [14,15]. This integration is supported by recent findings that show the effectiveness of the PBL-STEM combination in developing problem-solving skills. A study proved that the integration of the two approaches significantly improved students' ability to analyze complex problems and develop innovative solutions [16]. Meanwhile, another study concluded that PBL-STEM synergy plays an important role in training students to connect theoretical knowledge with practical applications through contextual problem-solving scenarios[17]. Internationally, a study confirmed that this integrated approach is optimal for developing metacognitive skills essential in science problem solving[18]. This integration blends the structured strengths of the PBL phases with the STEM interdisciplinary approach, allowing students to not only solve problems but also understand the application of heat concepts in the context of technology and engineering. The uniqueness of this study is reinforced by the use of a digital platform that facilitates the visualization of the abstract concept of heat, which has not been optimized in similar studies. Thus, this study not only fills an integrative gap in the literature, but also offers an innovative solution to holistically improve students' problem-solving skills.

II. METHOD

This research is developmental research using the Plomp development model. The Plomp model consists of three stages, namely: (1) preliminary research covering needs analysis and literature review, (2) the development or prototype design stage covering product design, validation, evaluation, and revision, and (3) the assessment phase focusing on field testing of the product[19]. In this study, the stages were limited to practical testing through small groups. The product developed was an electronic worksheet based on an integrated PBL-STEM model on heat material to improve students' problem-solving skills.

In the preliminary research stage, a needs analysis was conducted through diagnostic tests, teacher interviews, and literature reviews to determine students' problem-solving abilities and the availability of teaching materials. The development stage was carried out by designing a prototype of an electronic worksheet based on PBL-STEM, followed by self-evaluation, validation by experts, and product revision according to validator input.

The validity results are measured using the Aiken V static formula which is formulated as follows:

$$V = \frac{\Sigma s}{n(c-1)} \qquad \text{with, } s = r - l_0 \qquad (1)$$

After the rater agreement index is obtained, the validity category is determined based on Aiken's V value. V values of less than 0.4 are categorized as “invalid”, values between 0.4 to 0.8 are considered ‘valid’, and values of more than 0.8 are categorized as “very valid” [20].

Next, in the assessment stage, practicality was tested through one-to-one trials with three students with different abilities and small group trials with nine students. Practicality data was analyzed using percentages with the following formula:

$$Values = \frac{score\ obtained}{maximum\ score} \times 100\% \qquad (2)$$

Practicality assessment is determined based on the score interpretation criteria obtained, namely 81-100% (Very Practical), 61-80% (Practical), 41-60% (Practical Enough), 21-40% (Less Practical), and 0-20% (Not Practical) [21].

III. RESULTS AND DISCUSSION

Result

In the preliminary research stage of the Plomp Model, a diagnostic test of problem solving skills was conducted on students of class XI IPA and semi-structured interviews and questionnaires to physics teachers at SMAN 1 Bonjol. The test was given to 30 students who had studied heat, with an average score of 35.19%, indicating a low level of problem solving skills. Meanwhile, the results of the physics teacher interview revealed that the learning model used was not optimal in stimulating these skills, due to constraints such as time constraints, lack of focus on the learning stages, and unstructured implementation. In addition, conventional teaching materials such as printed books and LKPD do not support the implementation of learning models effectively, because the content and presentation do not include specific activities to train problem solving, and do not provide clear guidance for students in undergoing the learning stages as a whole. As a result, the current learning process has not been able to adequately develop students' problem solving skills.

Next is the development stage, the product produced in the form of PBL-STEM-based Electronic LKPD on heat material. The design of this LKPD is arranged following the stages of Problem Based Learning (PBL), namely: (1) orienting students to the problem, (2) organizing students to learn, (3) guiding investigations, (4) developing and presenting results, and (5) analyzing and evaluating solutions. Each of these stages is integrated with the STEM approach so that learning activities not only emphasize understanding of physics concepts, but also linkages with technology, engineering, and mathematics. In addition, in this LKPD, the PBL stages are combined with the indicators of problem solving skills according to Polya, namely: understanding the problem, planning the solution, implementing the solution, and re-examining the solution results. This integration allows students to practice solving problems systematically, reflectively, and purposefully.

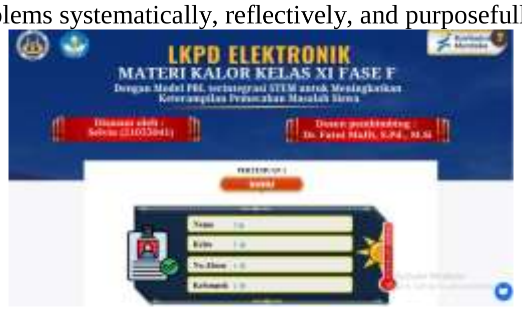

Fig. 1. Electronic LKPD Display

After the product was ready, a self-evaluation was conducted by the researcher to review the developed electronic worksheet, identify its weaknesses, check the completeness of the prototype, revise the inadequate parts, and add the necessary components. This process was conducted prior to validation by experts. The average result of the self-assessment reached a score of 87%, which was categorized as excellent. After the self-assessment, the next stage was validation with a physics expert lecturer from UNP. Expert validation showed that the LKPD had a very high level of validity with an average of 0.95. All aspects ranging from material substance, appearance, learning design, software utilization, PBL integration, STEM integration, to aspects of problem solving skills are in the "very valid" category. These results indicate that the content of the LKPD is in accordance with the content standards, learning construction, and supports the targeted skills.

Table 6. Results of Electronic LKPD Product Validation by Expert Lecturers

No	Aspect	Value	Category
1	Substance of the material	0,96	Highly valid
2	Visual communication display	0,933	Highly valid
3	Learning design	0,953	Highly valid
4	Use of software	0,972	Highly valid
5	Model *Problem Based Learning*	0,95	Highly valid
6	STEM	0,94	Highly valid
7	Problem-solving skills	0,96	Highly valid
	Average	0,95	Highly valid

After validity, a practicality test was conducted through the one to one and small group stages. In the one-to-one stage, the attractiveness aspect obtained the highest score (93%), while the efficiency aspect was relatively lower (84.72%). This shows that the product successfully attracted students' attention, but the efficiency of its use can still be improved, for example by simplifying instructions or navigation. The small group trial showed a similar pattern: attractiveness remained the aspect with the highest score (93%), while efficiency also showed the lowest result (84.72%). Interestingly, the average value of small group practicality (87.79%) was slightly higher than the one-on-one test (86.41%). This indicates that using the NLPD in a collaborative context provides a smoother and more practical learning experience than individual use.

After validation, practicality tests were conducted through one-to-one and small group stages with students. The following are images of the results of the one-to-one and small group practicality tests.

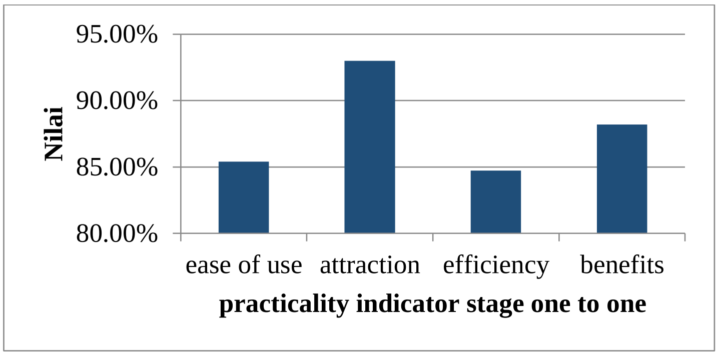

Fig 2. Practical Results of LKPD One-to-one electronics

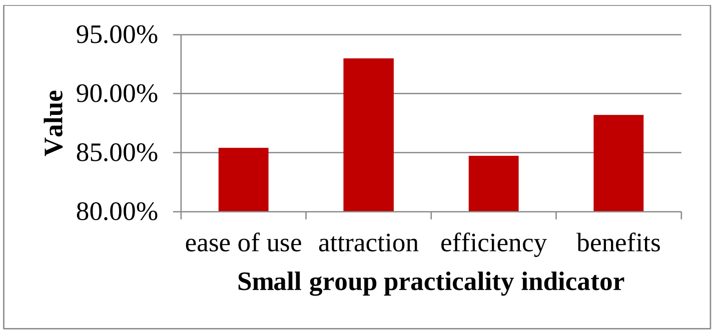

Fig 3. Practical Results of Electronic LKPD in Small Groups

Discussion

The development process in this study refers to Plomp's Development Model, which includes the initial research, prototype, and assessment stages. In the initial stage, a needs analysis was conducted, including initial studies on students and learning materials, interviews with physics teachers, and field observations. The results showed that students' problem-solving ability in the topic of heat was relatively low, as evidenced by a valid diagnostic test. In addition, teaching materials used in schools are still limited to printed books and non-interactive student worksheets (LKPD), which do not support the development of students' problem solving skills. This becomes the basis for developing PBL-based electronic LKPD integrated with STEM, as an effort to present teaching materials that are more contextual and interactive to build students' problem solving skills.

The electronic LKPD in this study was developed to measure students' problem solving skills in heat. In this discussion, the results of the research that has been conducted for the entire study will be discussed. Based on the results of the validity test, it was found that the electronic LKPD is very valid to be used to stimulate students' problem solving skills with an overall average score of 0.95 in terms of the following aspects.

First, the material substance aspect. The aspects presented are in accordance with the learning standards and achievement indicators, so that the content developed is able to become a directed learning tool. This is in line with research that confirms that the substance of the material in teaching materials must be arranged based on learning objectives in order to develop students' conceptual understanding appropriately [22].

Second, in terms of visual communication, the LKPD design utilizes graphic elements, layout, and interactive navigation that support student focus and engagement. An attractive appearance can help students understand information more effectively. This finding strengthens the results of research which states that interactive visualization in teaching materials can increase learning motivation while reducing student boredom in learning [23].

Third, the learning design aspect. LKPD has contained learning outcomes, learning objectives, and achievement indicators that are consistent with PBL syntax. Learning activities direct students to experience the stages of problem solving systematically, from identifying problems to evaluating solutions. This is in accordance with the explanation that PBL-STEM-based learning design is effective in building analytical and collaborative mindsets [24]. An important difference from this study is the emphasis on presentation of results through digital media which has rarely been explored in previous studies, even though this has been shown to improve students' scientific communication skills[25]. Thus, the learning design on this LKPD not only facilitates the systematic thinking process, but also strengthens the collaborative dimension and digital literacy of students [26].

Fourth is the use of software The results of the validation of the use of software are classified in the very valid category. This component is said to be very valid because the LKPD made is interactive to provide feedback to users, the LKPD also uses other supporting software, and the LKPD made is an original work. LKPD Elektonik can be done through smartphones and laptops. While the supporting websites used in this Electronic LKPD are Wizer.me and Geogebra.

The fifth is the Problem Based Learning Model, with average validation results classified as very valid. The Problem Based Learning component is said to be valid because each PBL syntax has been explicitly reflected in the activities in the LKPD, starting from problem orientation to evaluation of the problem solving process.

sixth is STEM (Science, Technology, Engineering, Mathematics), with average validation results classified as very valid. This STEM component is said to be valid because the activities in the LKPD link science with technological applications, engineering design, and mathematical modeling. This is in accordance with the statement that the STEM approach emphasizes integration across disciplines in solving problems contextually and collaboratively [2].

Seventh, the high validity of the problem-solving skills indicator shows that the LKPD is able to stimulate students to understand, design strategies, implement, and evaluate problem solving. This is in line with research which states that physics learning is effective when it encourages students to analyze phenomena, connect variables, and draw logical conclusions [28]. Thus, this LKPD can be a means to build systematic thinking skills.

In addition to validity, the results of the practicality test show that the LKPD is easy to use, efficient, and provides an interesting learning experience. PBL-STEM-based LKPDs tend to obtain a high level of practicality due to their ease of access and interactivity. This shows that the development of digital teaching materials can be a solution in increasing student engagement in physics learning [7]; [14].

In terms of practical implications, this development provides an alternative for physics teachers in presenting more interesting and meaningful learning. Teachers can utilize this electronic LKPD not only as a learning resource, but also as a systematic guide in training students' problem solving skills. For students, the use of this product opens up opportunities to be more active in the learning process, train independence, and develop an integrated understanding of science, technology, engineering, and mathematics concepts.

However, this study has limitations. The development was only carried out on heat material and the trial stopped at the small group practicality stage, so the generalization of the results is still limited. In addition, the challenges of implementation in schools with limited digital access have not been revealed in depth. In fact, infrastructure factors and technological readiness are important issues that can affect the effectiveness of using electronic LKPD. This analysis shows that although the developed products are practical and valid, the success of their implementation is highly dependent on the availability of digital facilities and the competence of teachers in utilizing them.

Therefore, future research is recommended to continue to the effectiveness test stage by involving a wider and more diverse sample. In addition, it is necessary to explore the application on other physics topics as well as study the implementation challenges in schools with limited digital infrastructure. Thus, the results of the study can provide a more comprehensive picture of the potential, opportunities, as well as obstacles to the use of PBL-STEM-based electronic LKPD in improving students' problem solving skills.

IV. CONCLUSION

The developed electronic LKPD is proven to be able to support the development of students' problem solving skills through systematic integration of the PBL model with Polya's indicators. Each learning step, from problem identification to solution evaluation, is directed to train students in understanding problems, designing solution strategies, and reflecting on the results obtained. With the addition of STEM elements that are contextually integrated in the heat material, this LKPD provides a learning experience that encourages students to link physics concepts with real applications, so that problem solving skills can develop more deeply and applicatively.

The uniqueness of this research lies in the explicit integration of Polya's framework and the PBL-STEM approach in the E-LKPD format, which is still rarely studied in the context of high school in Indonesia. This finding implies that physics learning can be directed towards a hybrid model that is more interactive, collaborative, and adaptive to the needs of the 21st century. In the future, similar research can be expanded through effectiveness testing on a larger scale, involving various school contexts, and utilizing technological support such as artificial intelligence to personalize learning activities, so that the products developed can contribute more significantly to science learning innovation at the national and international levels.

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