PILLAR OF PHYSICS EDUCATION
Vol. 19 (4), 2026, pp. 441–453
ISSN (Print) : 2337-9618
ISSN (Online) : 2684-8880

DESIGN OF A PHYPHOX-ASSISTED PBL-BASED ELECTRONIC STUDENT WORKSHEET TO FACILITATE STUDENTS' CREATIVE THINKING SKILLS IN THE TOPIC OF MOTION ALONG A STRAIGHT LINE

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ABSTRACT

The creative thinking skills of students at SMAN 1 Lembah Melintang in physics classes remain low. Preliminary test results show an average creative thinking skill score of 33%. Meanwhile, the use of teaching materials and laboratory activities has not been optimal, so teaching materials are needed that can facilitate a more active problem-solving and inquiry process. This study aims to develop PBL-based Electronic Student Worksheets supported by Phyphox on the topic of Motion Along a Straight Line and to determine the validity and practicality of the product. This study employed the Research and Development (R&D) method using Plomp's development model, which consists of a preliminary research phase, a prototyping phase, and an assessment phase. The study was limited to the prototyping phase, which included prototype design, self-evaluation, expert review, one-to-one evaluation, and small-group evaluation. The one-on-one evaluation involved 3 students, while the small-group evaluation involved 9 students and 2 physics teachers. The validity of the product was analyzed using Aiken's V index, while its practicality was assessed based on the percentage of scores from teachers and students. The results showed that the Electronic Student Worksheet achieved an average Aiken's V score of 0.93, falling into the "valid" category. The practicality test yielded a percentage of 92% from teacher evaluations and 89.25% from student evaluations; both results fell into the "highly practical" category. This study was limited to testing the validity and practicality of the product, while testing the effectiveness of the Electronic Student Worksheet on students' creative thinking skills can be conducted by future researchers. The developed Electronic Student Worksheet meets the criteria for validity and is highly practical for use as supplementary teaching material in physics instruction on the topic of motion along a straight line.

Keywords: Electronic Student Worksheet; Problem-Based Learning; Phyphox; Motion Along a Straight Line; Creative Thinking.

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I. INTRODUCTION

The development of science and technology in the 21st century demands that education be oriented not only toward the mastery of knowledge but also toward the development of the skills students need to face various problems [1]. One of the most important skills to develop is creative thinking. In physics education, this skill is essential because students are not only expected to understand concepts and equations but also to analyze phenomena, conduct investigations, and find solutions to problems [2,3].

In this study, creative thinking skills are defined according to Munandar's framework [4]. Based on this framework, creative thinking skills are identified through four indicators: fluency, flexibility, originality, and elaboration. Fluency is the ability to generate many ideas or answers relevant to a problem; flexibility is the ability to generate ideas from various perspectives or different categories; originality is the ability to generate ideas that are unconventional or different from common ideas; and elaboration is the ability to develop and elaborate on an idea. These four indicators are also used as aspects of creative thinking skills in research on physics learning [5].

One learning model that can support the development of creative thinking skills is Problem-Based Learning (PBL). PBL uses a problem as the starting point for learning and involves students in identifying problems, conducting investigations, gathering and analyzing information, and formulating solutions. These stages provide students with the opportunity to develop various ideas and alternative solutions to problems. Research shows that the implementation of PBL can support the improvement of students' creative thinking skills [6], including in physics learning, which encompasses the aspects of fluency, flexibility, originality, and elaboration.

However, conditions in the field indicate that students' creative thinking skills still need to be developed. Based on the initial creative thinking skills test administered to students at SMAN 1 Lembah Melintang, the average score was 33%, which falls into the low category. The test covered four indicators: fluency, flexibility, originality, and elaboration. These results indicate that students still struggle to generate ideas, identify various alternative solutions, and elaborate on their answers in greater detail.

Findings from observations and interviews with physics teachers indicate that instruction has incorporated Problem-Based Learning (PBL) and Project-Based Learning (PjBL) models; however, the application of these methodologies and students' active engagement have not yet been optimal. Some students still tend to be passive, lack confidence in expressing their ideas, and tend to follow the solution examples provided by the teacher. In addition, the teaching materials used are still dominated by printed materials, while the worksheets used are still simple and have not been designed interactively to guide students in conducting investigations and solving problems.

One alternative that can be used to address this issue is the development of PBL-based Electronic Student Worksheets. Electronic Student Worksheets can systematically present content, problems, activity guidelines, and inquiry-based activities in digital form [7]. Integrating PBL into Electronic Student Worksheets can provide students with the opportunity to actively engage in identifying problems, developing ideas, conducting investigations, and formulating solutions. In physics education, electronic teaching materials and modules that integrate creative thinking skills have the potential to support the development of these skills [8,9].

In addition to teaching materials, limited laboratory facilities pose a challenge to conducting physics experiments. Based on observations, experimental activities have not been carried out optimally, so students' opportunities to directly observe, measure, and analyze data remain limited. One alternative that can be used is the Phyphox app, which utilizes smartphone sensors to conduct various physics experiments [10]. Phyphox has been used to collect physics experiment data and has been integrated into the Electronic Student Worksheet for physics lab sessions [11]. Therefore, integrating Phyphox into PBL-based Electronic Student Worksheets can support inquiry-based learning on the topic of motion along a straight line through activities involving measurement, data collection, and direct analysis of phenomena.

Several previous studies in the field of physics have developed instructional materials relevant to this research. Study [12] developed PBL-based physics worksheets on motion along a straight line to improve students' conceptual understanding, while study [11] developed Phyphox-assisted e-worksheets for physics lab experiments on simple harmonic motion for the same purpose. Both studies demonstrate that PBL and Phyphox can serve as a foundation for developing physics instructional materials. However, each study has only addressed some of the necessary aspects. The PBL-based worksheet on motion along a straight line [12] did not utilize Phyphox, so its experimental activities did not address the limitations of laboratory equipment. Conversely, the Phyphox-assisted e-worksheet [11] has not yet utilized PBL methodology and was developed for a different topic. Furthermore, both studies are oriented toward conceptual understanding; thus, creative thinking skills have not been explicitly targeted through indicators of fluency, flexibility, originality, and elaboration.

Based on the author's literature review, no digital worksheets (Electronic Student Worksheet) have been found that integrate PBL, Phyphox, and creative thinking skills into the topic of motion along a straight line within a single instructional resource. The novelty of this study lies in the combination of these three components: the PBL framework is used as the structure for learning activities, Phyphox serves as a data-driven inquiry tool that overcomes the limitations of laboratory equipment, and the four indicators of creative thinking are integrated as learning objectives into the learning activities on the topic of motion along a straight line. Therefore, this study aims to develop an Electronic Student Worksheet based on Problem-Based Learning (PBL) assisted by Phyphox on the topic of motion along a straight line to facilitate creative thinking skills, as well as to determine the validity and practicality of the developed product. The Electronic Student Worksheet is expected to help students understand problems, conduct investigations using Phyphox, analyze data, and develop ideas to solve problems. This study was limited to the prototyping phase; therefore, the product's effectiveness in fostering creative thinking skills has not yet been tested.

II. METHOD

Type and Research Procedure

This study is a research and development (R&D) project aimed at producing an Electronic Student Worksheet on motion along a straight line based on Problem-Based Learning (PBL) and supported by Phyphox to foster students' creative thinking skills and to determine the validity and practicality of the product. The development model used is the Plomp model, which consists of three stages: preliminary research, the prototyping phase, and the assessment phase [13]. This study is limited to the prototyping phase.

The preliminary research phase was conducted to identify learning needs and issues through a needs analysis, an analysis of student characteristics, and a literature review. The needs analysis was conducted through interviews with physics teachers at SMAN 1 Lembah Melintang to obtain information regarding the learning process and the use of teaching materials. The analysis of student characteristics was conducted on 31 students in Class XI Fase F, focusing on learning activities, the use of technology in learning, and their initial creative thinking skills. The literature review was conducted by examining relevant sources on the PBL model, motion along a straight line material, Phyphox, Electronic Student Worksheet, and creative thinking skills.

The prototyping phase includes the design of a prototype, self-evaluation, expert review, one-on-one evaluation, and small-group evaluation [13]. During the prototype design phase, a PBL-based Electronic Student Worksheet on motion along a straight line was designed using Phyphox. Subsequently, evaluations were conducted in stages to identify shortcomings and revise the product. The self-evaluation was performed by the researcher to check for completeness before the product was submitted to validators. The expert review was conducted by five physics lecturers from the Faculty of Mathematics and Natural Sciences at Padang State University to assess the product's validity. Subsequently, a one-on-one evaluation was conducted with three students with low, moderate, and high ability levels. The small-group evaluation phase involved nine students with high, moderate, and low ability levels, as well as two physics teachers. The practical aspects assessed included ease of use and readability, presentation, efficiency, and the product's benefits.

Research Instruments and Data Analysis Techniques

The research instruments used included those from the preliminary research phase and the prototype phase. In the preliminary phase, the instruments consisted of interview forms, a student needs questionnaire, and a creative thinking skills test. Interviews were conducted with physics teachers to gather information about the learning process, instructional materials, and challenges encountered in the classroom. The questionnaire was administered to students to identify their needs regarding PBL-based Electronic Student Worksheet on motion along a straight line using Phyphox, while the creative thinking skills test was used to assess students' initial abilities based on the indicators of fluency, flexibility, originality, and elaboration. The creative thinking skills test was administered to 31 students in Class XI F1 at SMAN 1 Lembah Melintang and consisted of four essay-type questions on the topic of motion along a straight line. The questions were designed based on the four indicators of creative thinking skills according to Munandar [4], namely fluency, flexibility, originality, and elaboration.

During the development phase, the instruments included a self-evaluation form, an expert review form, and one-to-one and small-group questionnaires. Self-evaluation was conducted to check the completeness of the product and identify any errors, while expert validation was carried out by five faculty members from the Department of Physics, Faculty of Mathematics and Natural Sciences, Padang State University. The one-on-one testing was conducted with three students with low, moderate, and high ability levels, while the small-group testing was conducted with nine students with varying ability levels. The practicality testing also involved two physics teachers.

The validation sheets were grouped into six aspects: content substance, visual communication presentation, Electronic Student Worksheet components, software utilization (Phyphox), use of the PBL model, and creative thinking skills. Each item is rated on a 1–5 Likert scale. The teacher practicality questionnaire and the student practicality questionnaire consist of four aspects: ease of use and readability, presentation, efficiency, and benefits. Each item is rated on a 1–5 scale.

Validation data were obtained from the assessments of five expert validators using a validation sheet with a 1–5 Likert scale. Validity analysis was conducted using Aiken's V index to determine the level of agreement among validators on each aspect assessed. Aiken's V was calculated using the following formula:

$$V = \frac{\sum s}{n(c-1)} \tag{1}$$

$$s = r - l_0 \quad (2)$$

In this formula, (r) represents the score given by each evaluator, (l_0) is the lowest score used (1), (c) is the highest score (5), and (n) represents the number of evaluators. The resulting Aiken's V value was then interpreted using validity criteria. A value of ($V < 0{,}8$) falls into the "invalid" category, while a value of ($V \geq 0{,}8$) falls into the "valid" category. A product is deemed valid and suitable for use if the validity value obtained falls into the "valid" category. The obtained Aiken's V value is then interpreted based on the product validity criteria as shown in Table 1

Table 1. Aiken's Scale Categories

Interval	Category
$V < 0{,}8$	Invalid
$V \geq 0{,}8$	Valid

(Source: *Aiken* [14])

Next, the product's practicality was determined based on the results of questionnaires completed by teachers and students during the one-on-one and small-group stages. The practicality score was calculated by comparing the assessment score to the maximum possible score, then expressed as a percentage using the following formula:

$$P = \frac{S}{S_{maks}} \times 100 \quad (3)$$

In this formula, P is the practicality percentage (%), S is the obtained score, and S_{maks} is the maximum score. The practicality score obtained is then interpreted based on the criteria in Table 2 to determine the practicality level of the Electronic Student Worksheet.

Table 2. Practicality Scale Categories

Total Score Range	Category
81–100	Very High
61–80	High
41–60	Fair
21–40	Low
0–20	Very Low

(Source: Riduwan [15])

III. RESULTS AND DISCUSSION

Results

This study produced an Electronic Student Worksheet based on Problem-Based Learning (PBL) assisted by Phyphox to improve students' creative thinking skills in the topic of motion along a straight line. The development of the Electronic Student Worksheet was carried out using Plomp's development model, which includes the preliminary research stage, the prototyping phase, and the assessment phase. The research was conducted up to the practicality testing stage through small groups. Each stage yielded information and feedback that served as the basis for refining the developed product.

During the preliminary research phase, a needs analysis, an analysis of student characteristics, and a literature review were conducted. The results of the needs analysis indicated that student engagement in learning was still suboptimal, the implementation of innovative learning models still needed improvement, and laboratory activities on the topic of motion along a straight line were still constrained by a lack of laboratory equipment. The available teaching materials also do not fully support the development of higher-order thinking skills. Furthermore, the results of the student analysis showed that students still tend to be passive and have difficulty understanding concepts and connecting the "motion along a straight line" material to everyday phenomena.

The results of the initial analysis of creative thinking skills indicate that students' abilities are still in the low category. The initial test covered four indicators of creative thinking skills: fluency, flexibility, originality, and elaboration. The results of the creative thinking skills test for each indicator are presented in Figure 1.

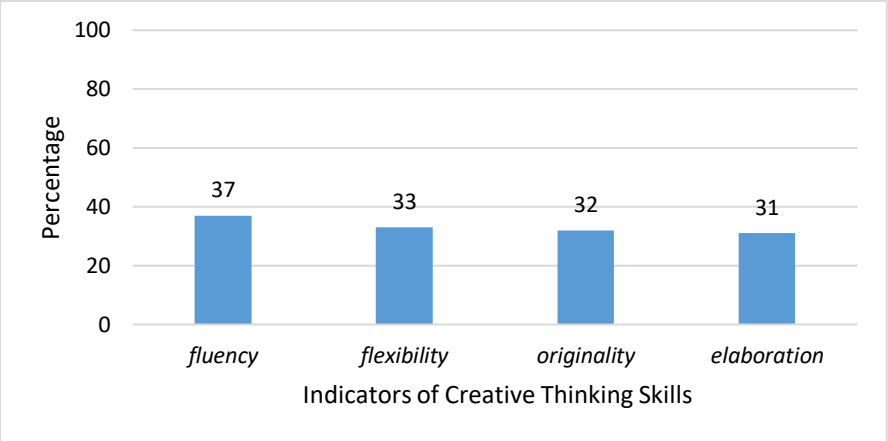


Figure 1. Students' Creative Thinking Skills Test Results

Preliminary test results for 31 students showed that the average creative thinking skill score was 33%, which falls into the low category. As shown in Figure 1, the fluency indicator scored the highest at 37%, followed by flexibility at 33%, originality at 32%, and elaboration at 31%. These results indicate that the students' ability to generate a variety of ideas (fluency), use various approaches or alternative solutions (flexibility), produce original ideas (originality), and develop and explain ideas in detail (elaboration) still needs improvement. Although the fluency indicator received the highest percentage, the results still indicate the need to develop creative thinking skills. A literature review was conducted on the Problem-Based Learning (PBL) model, Electronic Student Worksheet, motion along a straight line material, the Phyphox app, and creative thinking skills. The results of the review indicate that PBL can help students develop creative thinking skills through problem-solving activities that encourage the generation of various ideas and alternative solutions. Electronic Student Worksheet can facilitate systematic learning activities through problem presentation, investigative activities, data processing, and evaluation. Meanwhile, Phyphox can be used to support physics experiments and data collection via smartphone sensors. Based on these findings, the development of Electronic Student Worksheet is aimed at integrating PBL and Phyphox into a single instructional resource so that learning activities can foster the development of creative thinking skills through data-driven problem-solving and inquiry.

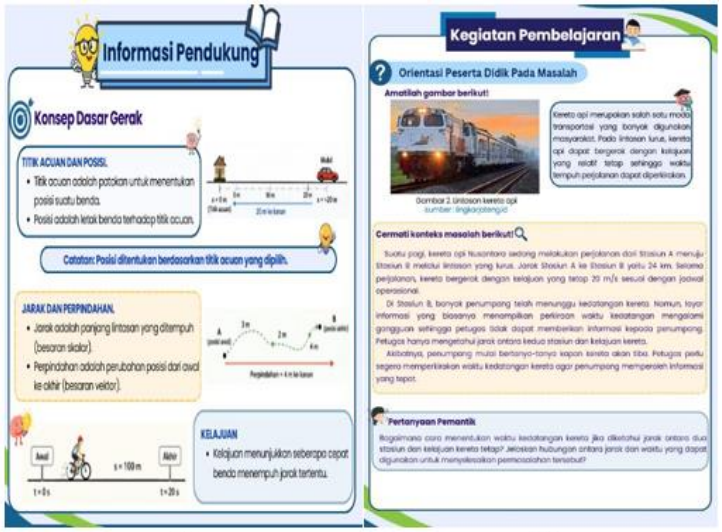
The prototyping phase resulted in the creation of an Electronic Student Worksheet based on Problem-Based Learning (PBL) and supported by Phyphox on the topic of motion along a straight line. The structure of the Electronic Student Worksheet consists of an introduction, a main body, and a conclusion. The introduction includes the cover, main menu, foreword, description of the Electronic Student Worksheet, instructions for use, and the competencies to be achieved. The main body consists of supporting information and learning activities, while the conclusion includes an evaluation, references, and the author's information.

Electronic Student Worksheet was developed using the TopWorksheets platform as an interactive electronic worksheet. Students access Electronic Student Worksheet via a link opened in a web browser—such as Google Chrome—on a smartphone or other compatible device. The Electronic Student Worksheet interface includes text, images, fill-in-the-blank fields, and navigation buttons to help students independently follow each part of the learning activity. Students enter their answers in the provided fields, including responses to guiding questions, measurement data, analyses, and conclusions in accordance with the activity instructions. After completing all activities, students click the "Finish" button to save and submit their answers via the TopWorksheets platform. Meanwhile, the Phyphox app is used separately to help students take measurements and collect experimental data for the "motion along a straight line" module. The introduction begins with a cover page featuring the title, identification information, target audience, logo, and characteristics of the PBL-based Electronic Student Worksheet supported by Phyphox. Next, a main menu is provided to make it easier for users to access each section of the Electronic Student Worksheet. The foreword provides a brief overview of the product's development objectives, while the Electronic Student Worksheet description explains the product's characteristics, PBL- syntax, and indicators of creative thinking skills. The user guide contains instructions for teachers and students, as well as explanations of the navigation buttons' functions. This section is supplemented with the competencies to be achieved, in the form of Learning Outcomes and Learning Objectives. The appearance of the Electronic Student Worksheet introduction section is shown in Figure 2.



Figure 2. Introduction Section of the Electronic Student Worksheet: (a) Cover, (b) Description of the Electronic Student Worksheet, (c) Main Menu, (d) Foreword, (e) User Guide, and (f) Competencies to Be Achieved

The main section contains supporting information and learning activities. The supporting information presents the basic concepts needed to study motion along a straight line. Furthermore, the learning activities are structured according to the PBL framework, which includes orienting students to the problem, organizing students for learning, guiding their investigation, developing and presenting results, and analyzing and evaluating the problem-solving process. These activities are integrated with indicators of creative thinking skills, namely fluency, flexibility, originality, and elaboration. During the investigation activity, students use the Phyphox app to collect and analyze motion data using smartphone sensors. A screenshot of the core section of the Electronic Student Worksheet is shown in Figure 3.



(a) (b)

Figure 3. Core Components of the Electronic Student Worksheet: (a) Supporting Information and (b) Learning Activities

The investigative activity utilizes Phyphox through two examples of activities. In Activity 1, students use an accelerometer sensor by placing a smartphone on a cart that is released from rest on an inclined track. Students record graphs of acceleration versus time, elapsed time, and track length, then determine the average acceleration and compare it with calculated results to conclude the type of motion the cart exhibits. In Activity 2, students used a microphone sensor (acoustic stopwatch) to measure the time it took for a ball to fall from various heights. Students recorded the height and fall time, calculated the acceleration due to gravity, then compared their results with9,8 m/s^2 and discussed sources of error.

Each activity includes questions that practice the four indicators of creative thinking. For example, for fluency, students are asked to list as many measurable quantities as possible related to the trolley's motion using a smartphone sensor. For flexibility, students determine the cart's acceleration using at least two different methods for example, from an acceleration-time graph and from the equations $= \frac{1}{2}at^2$. For originality, students design another experiment using everyday objects to determine gravitational acceleration using Phyphox. For elaboration, students describe in detail the steps for determining gravitational acceleration, along with their reasoning and methods for minimizing error. The concluding section consists of an evaluation, references, and the author's information. The evaluation includes questions to assess students' understanding of the material and competencies they have learned. The references list the sources used in the development of the Electronic Student Worksheet, while the author's information provides details about the author and the supervisor. The layout of the concluding section of the Electronic Student Worksheet is shown in Figure 4.



(a) (b) (c)

Figure 4. Concluding Section of the Electronic Student Worksheet: (a) Evaluation, (b) References, and (c) Author Information

Next, the prototype underwent formative evaluation, which included self-evaluation, expert review, one-on-one evaluation, and small-group evaluation. During the self-evaluation stage, the researcher examined the completeness of the structure, content, language, layout, and appropriateness of the Electronic Student Worksheet components using an evaluation instrument. The results of the examination showed that the structure of the Electronic Student Worksheet was appropriate, the layout had been improved to make it more attractive and user-friendly, and corrections had been made to typos, font types and variations, and color schemes. The results of the self-evaluation indicated that the Electronic Student Worksheet met the criteria examined and was deemed valid.

The developed Electronic Student Worksheet was then validated through an *expert review* phase. The validation was conducted by five experts who are physics lecturers at the Faculty of Mathematics and Natural Sciences, Padang State University**.** The validity assessment covered six components: content substance, visual communication design, Electronic Student Worksheet components, software utilization, use of the PBL model, and creative thinking skills.

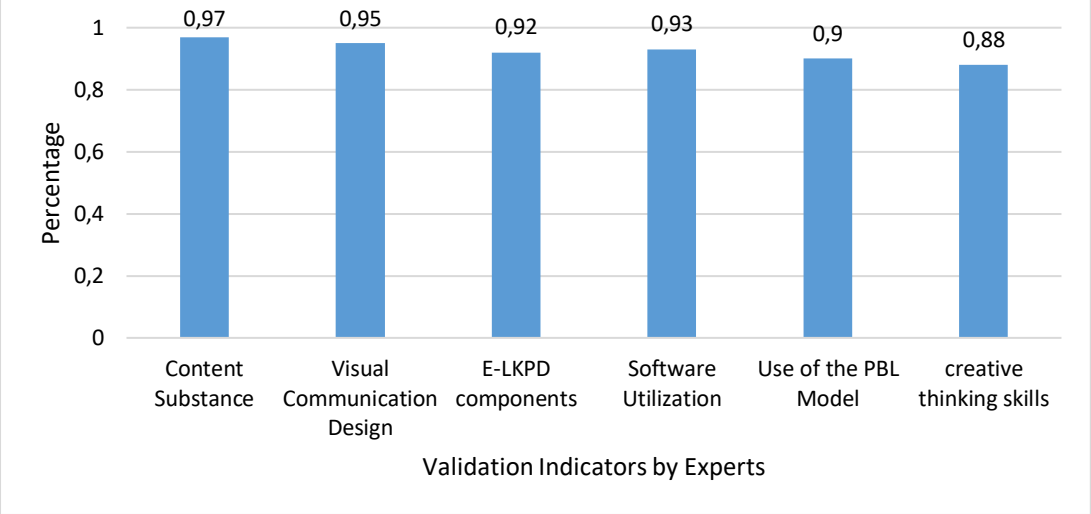


Figure 5. Expert Validation Results

Based on Figure 5, the validity scores of the Electronic Student Worksheet for each component ranged from 0.88 to 0.97. The highest score was in the content aspect, with a score of 0.97, while the lowest score was in the creative thinking skills aspect, with a score of 0.88. Overall, the average validity score of the Electronic Student Worksheet is 0.93, meaning that the developed Electronic Student Worksheet falls into the valid category. These results indicate that the content substance, visual communication presentation, Electronic Student Worksheet components, software utilization, use of the PBL model, and integration of creative thinking skill indicators have met the validity criteria based on expert assessments.

In addition to providing an evaluation, the validators also offered several suggestions and recommendations for improving the product. These suggestions included revising the problem orientation to avoid misconceptions, aligning the ATP and IKTP with the Merdeka Curriculum, improving the user guide, refining the cover and text, adding indicators of creative thinking, adjusting the PBL syntax, providing more space for answering prompt questions, refining the content, and correcting the images and equations in the vertical motion section. These suggestions and feedback were used as the basis for revising the Electronic Student Worksheet before conducting a practicality test.

After revisions were made based on the validation results, the Electronic Student Worksheet was then tested for practicality through one-on-one and small-group sessions. The one-on-one test involved three students with high, moderate, and low ability levels. The practicality assessment covered four components: ease of use and readability, presentation, efficiency, and benefits.

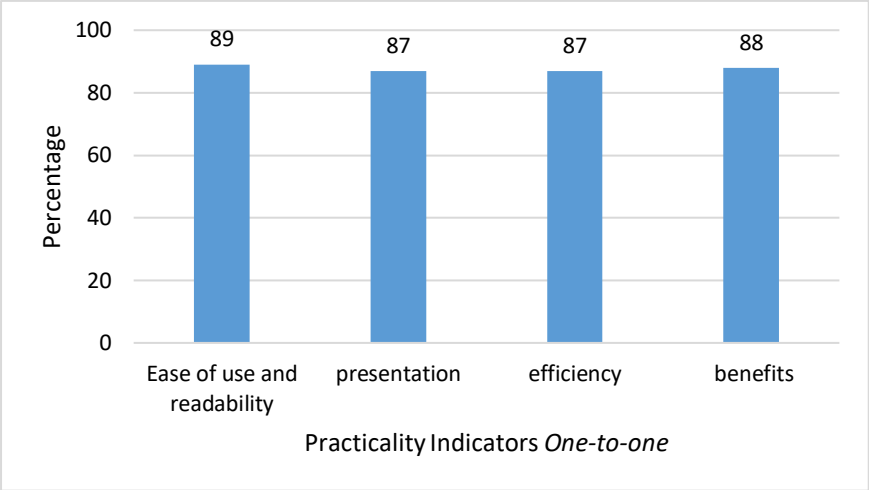


Figure 6. Results *of the One-on-One* Analysis

Based on Figure 6, the results of the one-to-one test showed a percentage of 89% for ease of use and readability, 87% for presentation, 87% for efficiency, and 88% for usefulness. The overall average score of 87.75% falls into the "very practical" category. Based on the results of the one-to-one test, improvements were made to several sections of the Electronic Student Worksheet based on student feedback and the difficulties they encountered while using the product. Improvements were primarily made to the experimental steps, which were deemed unclear and did not detail the activity stages sufficiently. Therefore, the instructions for each stage of the experiment were clarified and organized more systematically so that students could follow the investigative activities in the specified order. These improvements resulted in an Electronic Student Worksheet with experimental steps that are more structured, clear, and easy for students to follow, allowing the product to proceed to the small-group testing phase.

For example, before the revision, the measurement activity instructions consisted of only one general instruction: to conduct an experiment using Phyphox and record the data obtained. As a result, students did not know which experiment to choose, where to position their smartphone, or when to start and stop the measurement. After the revision, the instructions were broken down into numbered steps: open Phyphox and select the appropriate experiment; place the smartphone in the specified position; press the start button; perform the movement; stop the measurement; and record the data in the space provided. A practicality test of the Problem-Based Learning (PBL)-based Electronic Student Worksheet on motion along a straight line, supported by Phyphox, was conducted to determine the practicality of the developed product. The practicality test was carried out in a small group setting involving two physics teachers and nine students as users of the Electronic Student Worksheet. The assessment was conducted after the teachers and students used the Electronic Student Worksheet in learning activities covering the topic of motion along a straight line. The practicality assessment instruments for teachers and students covered four aspects: ease of use and readability, presentation, efficiency, and the benefits of the Electronic Student Worksheet.

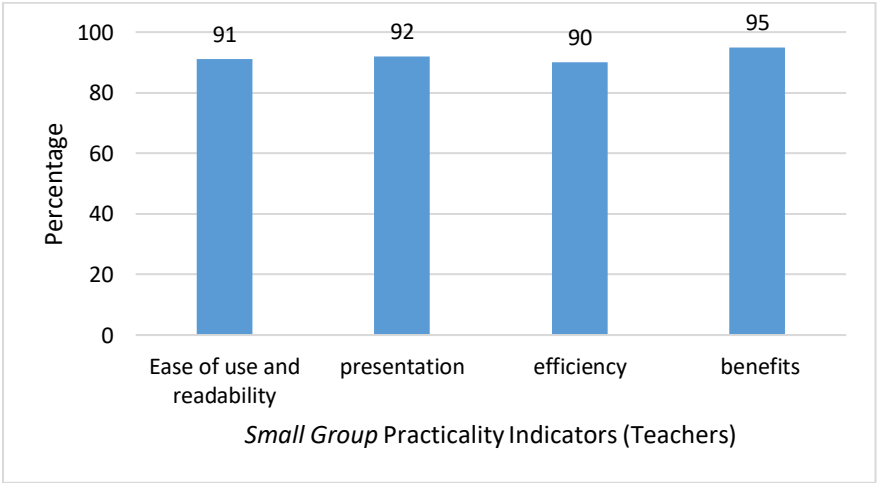


Figure 7. *Small Group* Analysis Results (Teachers)

Based on Figure 7, the results of teachers' practicality assessments of the Electronic Student Worksheet during the small-group stage showed a percentage of 91% for ease of use and readability, 92% for presentation, 90% for efficiency, and 95% for usefulness. The overall average score obtained was 92%, placing it in the "highly practical" category. These results indicate that the Problem-Based Learning (PBL)-based Electronic Student Worksheet on motion along a straight line, supported by Phyphox, is easy to use and provides benefits in supporting the learning process. Subsequently, a practicality test was conducted with students during the small-group stage to determine the level of practicality of the Electronic Student Worksheet based on student feedback.

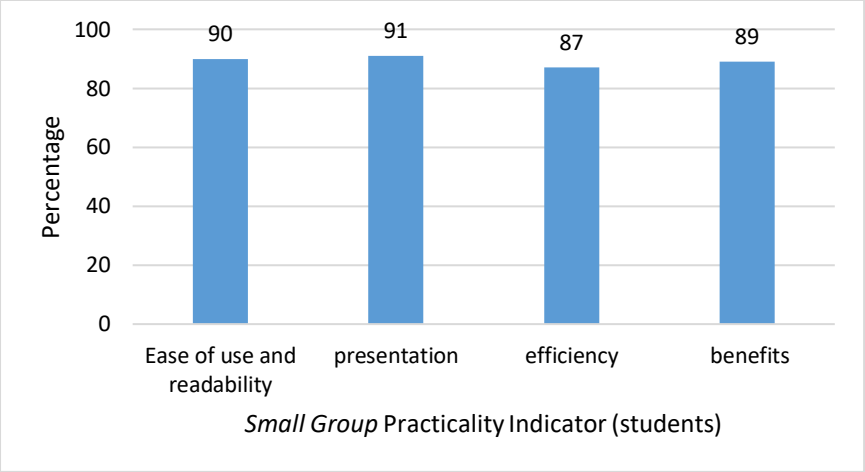


Figure 8. Results of the *Small-Group* Analysis (students)

Based on Figure 8, the results of students' practicality assessment of the Electronic Student Worksheet during the small-group stage showed a percentage of 90% for ease of use and readability, 91% for presentation, 87% for efficiency, and 89% for usefulness. The overall average score obtained was 89.25%, placing it in the "very practical" category. These results indicate that the Problem-Based Learning (PBL)-based Electronic Student Worksheet on motion along a straight line, supported by Phyphox, has an excellent level of practicality based on student feedback and can be used in motion along a straight line learning activities.

Discussion

During the preliminary research phase at SMAN 1 Lembah Melintang, it was found that student engagement in physics learning was still suboptimal, teaching materials were still dominated by print media, and laboratory activities on the topic of motion along a straight line were hindered by limited laboratory facilities. Teachers had implemented the PBL model, but its syntax had not been applied systematically; consequently, student engagement in problem-solving and inquiry was not yet optimal. The results of the initial test also showed that students' creative thinking skills fell into the low category (less creative) with an average of 33%, consisting of fluency at 37%, flexibility at 33%, originality at 32%, and elaboration at 31%. These conditions highlight the need for instructional materials that not only present content but also provide students with opportunities to solve problems, conduct investigations, and develop ideas. This need aligns with [2], which indicates that the learning process is linked to low levels of creative thinking skills; therefore, learning approaches that allow space for developing various ideas and alternative solutions to problems are necessary. Furthermore, [16] indicates that PBL-based Electronic Student Worksheets can support the development of creative thinking skills through learning activities consistent with the characteristics of PBL These findings strengthen the rationale for developing PBL-based Electronic Student Worksheets in this study to facilitate students in becoming more active in problem-solving and developing ideas regarding the topic of motion along a straight line.

PBL was chosen as the basis for designing activities in the Electronic Student Worksheet because it provides students with the opportunity to understand problems, conduct investigations, develop alternative solutions, and evaluate the results. PBL is a learning model that can be used to develop creative thinking skills in physics learning [3]. The application of PBL is also adapted to the characteristics of the motion along a straight line material, which relates to everyday phenomena, so that the problems presented serve as a starting point for students to connect the concepts of distance, displacement, velocity, and acceleration with the observed phenomena. This is consistent with [12], which shows that PBL-based worksheets on the topic of motion along a straight line can support learning through the problem-solving process. Furthermore, PBL-based e-worksheets can foster creative thinking skills through activities designed according to the PBL stages [17]. Activities that provide students with opportunities to

express ideas, gather information, and engage in discussions can also support the development of creative thinking skills [8].

Limitations in laboratory facilities were a key consideration in selecting Phyphox as a technology to support investigative activities. Phyphox utilizes smartphone sensors, allowing it to be used as a physics experiment tool when laboratory equipment is limited [10], and it can be integrated into digital worksheets for physics lab sessions [11]. Through Phyphox, students can collect data from observed phenomena and then analyze it to solve problems. The development of this Electronic Student Worksheet combines a problem-solving process based on PBL with Phyphox-assisted investigations, giving students the space to generate ideas, consider several alternatives, and develop more detailed answers in line with the indicators of creative thinking. This design served as the basis for developing the Electronic Student Worksheet during the prototyping phase.

The validation results show that the Electronic Student Worksheet meets the validity criteria across all evaluation aspects, including content substance, visual communication design, Electronic Student Worksheet components, software utilization, the use of the Problem-Based Learning (PBL) model, and creative thinking skills. The content substance component received the highest validity score, indicating that the material met the criteria for conceptual accuracy, scope of content, relevance to current knowledge, and readability. This is supported by the development of the material, which was based on a review of the literature and the learning outcomes for the topic of motion along a straight line. This finding aligns with the research by Nazira et al. [12], which showed that the feasibility of PBL-based physics worksheets on the topic of motion along a straight line is supported by the appropriateness of the content, the presentation of problem-based activities, and the design of the worksheets. Meanwhile, the creative thinking skills aspect received the lowest validity score; therefore, the relationship between the indicators of fluency, flexibility, originality, and elaboration and the learning activities needs to be addressed. In addition to the validators' assessments, the validation process also served as the basis for refining the product through improvements to the content and presentation of the Electronic Student Worksheet in accordance with the feedback provided. These improvements included adjustments to the material and learning activities, clearer instructions for use, and ensuring the alignment of activities with the PBL stages and creative thinking indicators.

A practicality test to evaluate the practicality of the product, conducted by two physics teachers, covered four aspects: ease of use and readability, presentation, efficiency, and the benefits of the Electronic Student Worksheet. The practicality results showed that the presentation aspect received the highest rating based on the teachers' responses, while the efficiency aspect received the lowest rating. The high rating for the presentation aspect was due to the systematic presentation of the Electronic Student Worksheet, which included contextual, everyday problems relevant to the students and was equipped with interactive navigation buttons (menu, next, home) that made it easier for teachers to guide the flow of learning in the classroom. This finding aligns with a study [16] showing that a structured worksheet with comprehensive learning components can serve as an effective guide for teachers in conducting PBL-based learning activities. Meanwhile, the low response regarding efficiency is likely due to the numerous steps involved in a single learning sequence—ranging from understanding the problem, reading the user instructions, operating the Phyphox application, recording measurement data, to analyzing errors and drawing conclusions. This sequence of PBL stages and digital experiments requires strict time management and very clear operational instructions so as not to overburden the allocated class time. This finding is consistent with a study [9] that discusses the practicality of physics teaching materials in terms of ease of use and their benefits in learning.

A practicality test conducted by nine students (small-group evaluation) on the same four aspects showed that the Electronic Student Worksheet falls into the "very practical" category. Students rated the "benefits" aspect highest, while the "presentation/readability" aspect received the lowest rating. The high score for the "benefits" aspect is related to hands-on learning experiences in which students were invited to observe phenomena, conduct independent experiments using smartphone sensors via Phyphox, and analyze data to demonstrate the concept of motion along a straight line in real life. This allows students to directly experience the usefulness of Electronic Student Worksheet in aiding conceptual understanding and problem-solving. This finding is supported by a study [11] showing that Electronic Student Worksheet for lab experiments assisted by the Phyphox app received very positive responses from students because it provided engaging, interactive inquiry activities that helped them understand physics concepts through hands-on experiments.

Based on the results of one-on-one and small-group testing, targeted improvements were made to the Electronic Student Worksheet work instructions. Before the revision, the experiment instructions consisted of only one general directive, which led to confusion among students regarding which type of Phyphox experiment to choose, the placement of the smartphone, and the start and end times for measurements. After the revision, the instructions were broken down into more detailed and systematic numbered steps. These improvements successfully enhanced the practicality of the Electronic Student Worksheet, clarified the sequence of tasks, and saved time during execution without reducing students' opportunities to practice creative thinking skills.

Overall, the PBL-based Electronic Student Worksheet supported by Phyphox on the topic of motion along a straight line that was developed meets the validity criteria and is highly practical for use in physics instruction. This study was limited to the prototyping phase, which included validation and practicality testing; therefore, the product's effectiveness in enhancing students' creative thinking skills has not yet been directly tested. Future research could continue the development through the assessment phase or field test using a pretest-posttest design on a broader sample, while also taking into account the diversity of smartphone sensor specifications used by students when operating Phyphox.

IV. CONCLUSION

Based on the research findings, an Electronic Student Worksheet on motion along a straight line based on Problem-Based Learning (PBL) and supported by Phyphox has been developed, featuring a design consisting of an introduction, main body, and conclusion. The main body includes the PBL stages integrated with inquiry-based activities using Phyphox, as well as activities that address the indicators of creative thinking skills: fluency, flexibility, originality, and elaboration. The developed Electronic Student Worksheet meets validity criteria and is highly practical, as evidenced by expert validation and practicality testing conducted by teachers and students. Thus, the developed Electronic Student Worksheet can be used as supplementary teaching material for instruction on the topic of motion along a straight line.

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