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Development of a Flipped Classroom-Based E-LKPD to Enhance Problem-Solving Skills in Particle Motion Dynamics

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Abstract

he limited use of effective learning media in developing students' problem-solving skills served as the basis for this study. This study focused on developing a flipped classroom-based e-LKPD on particle motion dynamics to enhance the problem-solving skills of 11th-grade students Research and development utilizing the ADDIE paradigm (Analysis, Design, Development, Implementation, Evaluation) was the research methodology used. A student response questionnaire and an expert validation questionnaire were among the tools utilized. Both quantitative and qualitative analysis were done. The created product is very appropriate for usage, as indicated by the average score of 91.94% in the product feasibility validation findings. The enhancement of pupils' ability to solve problems was classified as moderate, with an N-Gain value of 0.67, indicating that the use of flipped classroom-based e-LKPDs is effective in enhancing students' problem-solving skills. Student The average score for the answer results was 86.40%, which is considered very excellent. The results of this investigation have the potential to promote student-centered learning and enhance problem-solving skills.

Keywords: e-LKPD, Flipped Classroom, Learning Media, Problem-Solving, Particle Motion Dynamics

INTRODUCTION

Physics education prioritises active, collaborative and contextual learning experiences, so that students not only master concepts academically, but can also apply them in everyday life and in the context of technological advancements (Melianti, et al 2020; Sun & Yohandri, 2025). Ideal physics education does not merely focus on understanding the subject matter but requires the development of 21st-century skills through significant pedagogical innovation (Pratiwi & Rahmad, 2024; Riyanto et al., 2023). Digital technology's incorporation into education is crucial to enhance digital literacy among both teachers and students (Utama et al., 2025). Problem-solving ability can be understood as an individual's capacity to identify and address challenges, and it is a vital 21st-century skill required to navigate technological advancements across various aspects of life (Mu'minah, 2021).

Problem-solving ability is defined as an individual's skill in finding solutions through the process of acquiring and organising information, and accepting problems as challenges to be resolved (Siboro & Panjaitan, 2021). This skill is a core 21st-century competency that students must possess to face life's challenges (Dede, 2022). However, the reality on the ground indicates that students' understanding and problem-solving abilities remain low. More specifically, Erni Kusrini (2022) found that only 30% of Students can comprehend an issue, which is the most basic stage of problem-solving. This situation indicates that many students are not yet accustomed to following a systematic process from planning strategies, implementing solutions, to conducting evaluations and consequently often struggle when facing academic or everyday challenges. Students require resources that can facilitate their learning more effectively (Yanti et al., 2023). Therefore, serious efforts are required to analyse and simultaneously improve students' problem-solving skills, namely through Student Worksheets (LKPD).

Based on interviews with Year 11 students at State Senior High School 10, Bengkulu City, it was found that the school's internet connection is relatively stable and runs smoothly, although its use is still largely focused on specific learning activities requiring online access. Students have also utilised laboratory facilities and supporting equipment, such as projectors, in their learning activities. However, the majority of students reported that physics lessons still frequently lead to boredom. This indicates limitations in the approaches and media used, which are thus unable to effectively stimulate motivation and active student engagement in understanding the subject matter.

A number of studies on e-LKPDs based on the Flipped Classroom approach have shown encouraging findings in enhancing students' enthusiasm for learning and reading levels. The effectiveness of these learning materials is demonstrated by the e-LKPD developed by Wardhani et al. (2024), which is based on the flipped classroom approach and exhibits very high validity (97%), alongside a significant improvement in literacy skills, as shown by an average N-Gain of 0.65. The research to be conducted will develop Flipped Classroom-based e-LKPDs for senior secondary school physics learning, emphasising the use of interactive platforms such as Live Worksheets which have not yet been fully optimised and enhancing students' problem-solving abilities. This method is expected not only to boost motivation and literacy but also to facilitate access to self-directed learning anytime and anywhere, whilst enhancing interaction and discussion during face-to-face sessions, thereby creating contextual and adaptive digital learning materials.

Worksheets have been shown to be useful in helping pupils build their problem-solving skills in the subject of particle motion dynamics, as it encourages them to systematically analyse problems, devise solution strategies, and evaluate solutions through a series of specially designed contextual questions (Risamasu & Pieter, 2024; Riastuti et al., 2024). However, the use of printed worksheets as a teaching medium in the classroom has several drawbacks, such as a lack of encouragement for problem-solving; students are not actively engaged in problem-solving, thereby making the learning process less meaningful. Furthermore, the worksheets commonly utilized by educators in the process of teaching and learning often have an unattractive layout, which reduces students' interest and motivation to learn (Risamasu & Pieter, 2024; Riyanto et al., 2023). Given these problems, creativity is required in the development of conventional worksheets as an effective solution to address these limitations, namely by utilising current technological advancements, such as e-worksheets based on The model of the Flipped Classroom.

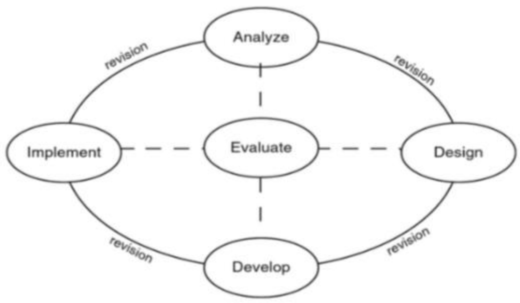
The paradigm of the e-LKPD Flipped Classroom has emerged as a creative way to address a number of learning challenges, particularly those involving active student engagement in the classroom and a lack of face-to-face interaction (Wardhani et al., 2024). Innovative approaches such as the Flipped Classroom have proven successful in boosting student motivation and understanding by combining pre-class activities (watching videos, reading materials, completing quizzes) with question-and-answer sessions, problem-solving, and in-class testing, as explained in the research (Nana & Venessa, 2024).

The novelty of this study lies in the integration of the flipped classroom model into the development of e-LKPDs as an effort to address the limitations of conventional, static learning media. This innovation will create a more structured learning system, consisting of pre-class activities that students complete independently using the interactive LiveWorksheets platform, as well as in-class sessions focused on reinforcing students' conceptual understanding. The use of the Problem-Based Learning (PBL) model distinguishes this e-LKPD from typical e-LKPDs. With its creative, interactive, and engaging design, this e-LKPD serves not merely as instructional material but also fosters students' independent learning and enhances their digital literacy in alignment with 21st-century competency requirements.

Given the backdrop described above, this study is designed to: describe the feasibility of flipped classroom-based e-LKPDs on particle motion dynamics, assess improvements in students' problem-solving skills, and examine students' responses to these e-LKPDs among Year 11 students.

METHODOLOGY

The type of research conducted is R&D stands for research and development. Sugiyono (2020) defines the research and development method as a process for creating a certain product and then identifying ways to improve it. This kind of study employs the ADDIE research design paradigm and is a development study. Analysis, Design, Development, Implementation, and Evaluation are the five phases of this methodology (Rusdi et al., 2022). Figure 1 depicts these phases.



(Branch, 2009)

Figure 1. The ADDIE Research and Development Stages

This study was conducted at SMAN 10 in Bengkulu City. Class XI H at SMAN 10 served as the study's population in Bengkulu City, comprising 30 students. The research sample was selected using purposive sampling, based on recommendations from the physics teacher, the students' varying abilities, the fact that the class had not yet used the developed teaching material, and its suitability for the material currently being studied. In the limited testing phase, a sample of 10 students was selected to assess the readability and comprehension of the developed e-LKPD. Subsequently, in the more comprehensive testing phase, 30 students (Class H) were selected to test the efficacy of the e-LKPD in enhancing students' capacity for problem-solving. This class was selected based on several criteria: the students in the class exhibited relatively homogeneous characteristics regarding cognitive abilities and prior learning; the class was supported by the subject teacher; and it was considered sufficiently representative of the entire student body.

Tests, questionnaires, interviews, and observation sheets were used as data gathering tools. Observations were used to directly observe the implementation of learning that utilised the e-LKPD as a learning medium. In-depth interviews were conducted with students who had used e-LKPDs in the learning process. The aim of these interviews was to explore their experiences, perceptions, and views regarding the benefits, advantages, and challenges of using this medium. Questionnaires were administered to respondents, comprising a student response questionnaire and a Validation survey for topic matter experts and media professionals Tests were administered to students to measure problem-solving skills, so that it could be analysed whether there was an improvement in problem-solving skills after participating in learning using this medium or not. There were two types of tests given to the students, namely: (1) a pre-test carried out before to using the physics e-LKPD and (2) a post-test administered after the use of the physics e-LKPD.

Systematically, the instrument used in this study adapts Polya's model flow, where the process begins with identifying the problem in the analysis stage, followed by developing a strategic solution plan. The next step is implementing the previously created plan, and concluding with a review to ensure the solution's appropriateness to the context.

The results of the assessment by three validators of the test instruments comprising a pre-test and a post-test—display that the validity percentages obtained were 81.82%, 94.55% and 96.36% respectively. Overall, the average percentage reached 90.91%, placing it in the 'highly valid' category. The assessment was based on several aspects, namely content, construction and language. Consequently, the test instruments used were deemed valid and suitable for measuring students' problem-solving abilities in learning using e-LKPDs based on the Flipped Classroom approach.

Data analysis in this study employed both both quantitative and qualitative approaches. Qualitative information was acquired from the suggestions and comments of the validators and teachers, as well as from observations during the learning process, which served as the basis for refining the developed e-LKPDs. Meanwhile, quantitative data were obtained from expert validation sheet scores, student response questionnaires, and Students' pre-test and post-test results were examined to see how well the e-LKPD improved their problem-solving abilities. The questionnaire data scores can be analysed using the formula in Equation 1 below:

$$\text{Validation} = \frac{\text{Total score}}{\text{Total ideal score}} \times 100 \quad (1)$$

The expert validation questionnaire scores were analysed using a 1–5 Likert scale and interpreted using the standards listed in Table 1. The student response questionnaire scores were also assessed using a 1–5 scale, with the interpretation criteria shown in Table 2. Furthermore, the assessment criteria for improvements in problem-solving based Table 3 displays the N-Gain scores.

Table 1. Validity Criteria

Percentage (%)	Category
0% - 20%	Highly Unacceptable
21% - 40%	Unacceptable
41% – 60%	Somewhat Acceptable
61% - 80%	Acceptable
81% - 100%	Highly Acceptable

(Masyruhan et al., 2020)

Table 1 presents the validity assessment criteria used to assess the created product's appropriateness. These criteria are presented as percentage ranges classified into five categories: highly unsuitable, unsuitable, moderately suitable, suitable, and highly suitable. Using these criteria, the assessment results from the validators can be systematically interpreted to determine the extent to which the developed product meets the suitability standards.

Table 2. Assessment Criteria for Student Response

Percentage (%)	Category
0% - 20%	Very Not Good
21% - 40%	Not Good
41% – 60%	Fairly Good
61% - 80%	Good
81% - 100%	Very Good

(Kartini & Putra, 2020)

Table 2 shows the criteria for assessing pupils' responses to the use of e-LKPDs in learning. This assessment is based on the percentage of marks obtained and is grouped into several categories, ranging from very poor to very good. These criteria are used to describe the level of acceptance and response of pupils to the learning media employed.

Table 3. N-Gain Level Criteria

Average	Criteria
$g > 0,7$	High
$0,3 \leq g < 0,7$	Moderate
$g < 0,3$	Low
$g \leq 0$	No Improvement

(Wahab et al., 2021)

Table 3 presents the N-Gain level standards that are used to gauge the improvement in students' problem-solving skills following the learning process. These N-Gain values are categorised into several groups: high, moderate, low, and no improvement. These criteria are used to analyse the improvement in students' problem-solving outcomes through e-LKPD use based on the Flipped Classroom approach.

RESULTS AND DISCUSSION

1) Analysis Stage

The development of Flipped Classroom-based e-LKPDs began with direct observation and in-depth interviews with physics teachers and a number of students to identify various obstacles encountered, particularly in accessing and comprehensively understanding the material on the dynamics of motion. Based on the observations carried out, it was found

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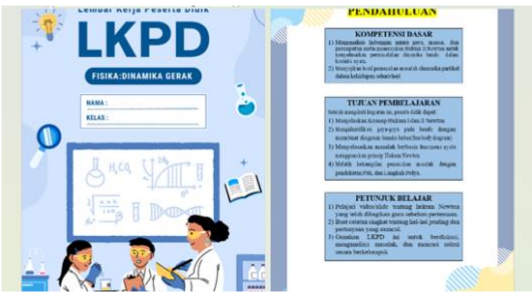
that learning activities at school tended to rely solely on printed teaching materials, whilst non-printed materials typically used included PowerPoint displays and instructional films. The lack of interactive learning media resulted in low student enthusiasm for physics lessons and led students to perceive physics as a difficult subject. Consequently, the development of teaching materials is essential to make physics lessons in the classroom more engaging and interactive.

2) Design Stage

Once the observation results have been obtained, the next stage is a structured, comprehensive and systematic design process. The design process involves developing a framework for the e-LKPD that includes essential components, such as the formulation of learning objectives aligned with core competencies, the gradual development of teaching materials on particle motion dynamics, and the design of learning activities that support the implementation of the Flipped Classroom model. In addition, practical and reflective exercises were developed, along with assessment tools to measure student achievement holistically. The Flipped Classroom-based e-LKPD design using the PBL learning model is presented in Figure 2.

Before revision



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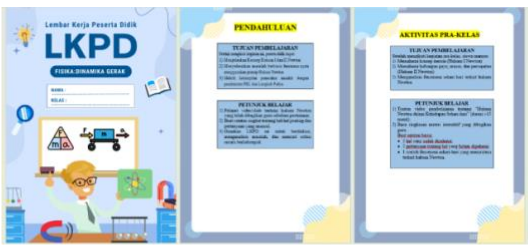

Figure 2. Design of the Flipped Classroom-based e-LKPD

According to the experts' validation findings, the E-LKPD developed in the initial phase has, on the whole, demonstrated good quality. Nevertheless, there are still some sections that require improvement. One of the main suggestions relates to the cover design, which was deemed unable to accurately reflect the overall content of the material. The cover design does not reflect the learning topics discussed within the E-LKPD, thus failing to demonstrate a clear connection between the initial presentation and the content presented. Furthermore, the validators provided feedback regarding the core competencies section, which was deemed no longer in use, and therefore recommended for removal. Consequently, revisions were made to adjust the cover design to make it more relevant to the material and to remove the core competency section, thereby providing learners with a clearer and more accurate picture of the e-LKPD's content.

3) Development Stage

Subsequently, the Flipped Classroom-based e-LKPD design, utilising the Problem-Based Learning (PBL) model, will undergo testing and evaluation by validators prior to its implementation in schools. The validators' assessment covers content suitability, language suitability, presentation suitability, and media suitability, as shown in Table 4.

Table 4: Learning Media Validity Results

Assessment Aspect	Response	
	Score	Qualitative Category
Content Suitability	92,22%	Highly Acceptable
Language Suitability	93,33%	Highly Acceptable
Presentation Suitability	86,67%	Highly Acceptable
Media Suitability	95,56%	Highly Acceptable

Table 4 presents the information on the reliability of the educational materials created based on the validators' assessment. The developed e-LKPDs have met the criteria based on the findings of the validation of appropriateness as educational media The validators assessed that the content presented was consistent with physics concepts and relevant to the learning objectives. The language used was deemed communicative, clear, and simple for pupils to comprehend. Additionally, the presentation of the media was considered to have been designed systematically and engagingly, and included activity steps that support the implementation of the flipped classroom model.

However, there are several points raised by the validators that require attention. The validators suggest that the cover design be adapted to the concept of particle dynamics so that it better reflects the content of the material. Furthermore, some incomplete sentences were still found on the media validation sheet, so improvements are needed. The validators also recommend that the depth of the subject matter be enhanced to ensure a more comprehensive presentation of the material. The developed e-LKPD is deemed suitable for use in physics teaching with some improvements, based on the evaluation's findings and comments.

4) Implementation Stage

Following the validation stage, The e-LKPD based on Flipped Classrooms was tested on Year 11 students at SMAN 10, Bengkulu City. This test aimed to assess students' responses to the Flipped Classroom-based e-LKPD on the developed particle motion dynamics material. A A survey of student responses was conducted to get an understanding of students' reactions to the use of the e-LKPD throughout the process of learnin Response measurement was conducted using a Likert scale designed to assess students' attitudes and perceptions towards the learning media used. The responses provided by students represent their reactions to the stimuli received, and can therefore be utilised to determine the level of acceptance and the benefits of the media. The indicators in the response questionnaire covered features of interest, usability, material clarity, utility, and interaction. The produced product received an average score of 86.40% from students, placing it in the "very good" category. Table 5 displays the findings from the examination of students' answers to the Flipped Classroom-based e-LKPD.

Table 5. Results of Student Responses to the Flipped Classroom-based e-LKPD on the topic of particle motion dynamics

Assessment Aspect	Response	
	Score	Qualitative Category
Content	85,83%	Very Good
Media	85,56%	Very Good
Benefits	87,33%	Very Good
Language	86,67%	Very Good

Based on Table 5, it can be seen that students' responses to the flipped classroom-based e-LKPD on the topic of particle motion dynamics fall within the 'very good' category. This aligns with the findings of Septiani et al. (2021) on the Development of Blog-Assisted Flipped Classroom-Based E-Learning on the Topic of Momentum and Impulse. The research results indicate that this learning tool is valid and practical, and has received positive feedback from students, particularly regarding independent learning activities prior to class and interactive discussions during face-to-face lessons. The research results indicate that the implementation of the flipped classroom-based e-LKPD received a positive response from students due to the ease of use of digital media, which can be accessed anytime and anywhere. Furthermore, the flipped classroom-based e-LKPD aligns with the characteristics of 21st-century learning which is adaptive and interactive thereby fostering students' independent learning, digital literacy, and critical thinking skills.

Table 6. N-Gain results from pre-test and post-test scores

Indicator	Average Pretest Score	Average Posttest Score	N-Gain Score
Understand the problem	72.5	92.08	0.71
Plan problem resolution	47.083	75	0.52
Solve the problem	51.6	90.8	0.81
Check again	44.5	81.6	0.66
Average			0,67

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The improvement in The N-gain equation was also used to analyze the utilization of the created flipped classroom-based e-LKPD. The improvement in students' comprehension before and after utilizing the flipped classroom-based e-LKPD may be ascertained using the pre-test and post-test findings. According to the research, the N-gain value is 0.67, which is in the moderate range. The application is credited with helping kids become more adept at solving problems of the flipped classroom approach in the e-LKPD, which enables students to study the material beforehand prior to classroom learning activities. Through the e-LKPD, students receive preliminary resources in the form of material summaries, instructional videos, and prompt questions that help build an initial understanding of the concepts to be studied. Consequently, when the learning process takes place in the classroom, students no longer begin learning from scratch but already have a conceptual framework, allowing learning time to be focused more on discussion and problem-solving activities.

The implementation of the flipped classroom in classroom instruction makes a tangible contribution to optimizing the allocation of learning time and the depth of student understanding through a structured division of learning activities between independent study and in-class sessions. The use of flipped classroom-based e-LKPDs, equipped with instructional videos and explanations of particle motion dynamics that begin with a prompt question, can help students build initial understanding independently before face-to-face activities at school. This allows for more efficient use of classroom time for more productive activities, such as group discussions and collaborative problem-solving analysis.

This approach encourages students to be more active in analysing problems and applying the concepts they have learnt, thereby improving their problem-solving skills. These results are consistent with research conducted by Novriani et al. (2021) on the development of an Android-based e-LKPD on momentum and impulse to improve students' conceptual understanding. The results of the development showed that the improvement in the e-LKPD was also reflected in an increase in students' conceptual understanding, with an N-gain score of 0.73; this demonstrates that technology-based interactive e-LKPDs are capable of enhancing the quality of physics learning. Meanwhile, research conducted by Haque et al. (2021) on the application of the flipped classroom model supported by interactive e-books demonstrated a significant improvement in students' literacy competencies and academic outcomes, which was also supported by positive feedback from teachers and students regarding the ease of using digital media as self-directed learning materials at home.

Based on the research findings, it can be concluded that the flipped classroom-based e-LKPD on particle motion dynamics received a positive response from students as it made classroom learning activities more interactive and enabled students to play an active role in the learning process from start to finish.

CONCLUSION

The flipped classroom-based e-LKPD on particle motion dynamics has been deemed suitable for use based on expert evaluations of its content, presentation, language, and media. The flipped classroom-based e-LKPD can improve students' problem-solving skills. Students also provided positive and favorable feedback regarding the flipped classroom-based e-LKPD. Although it yielded positive results, this study has several shortcomings or limitations. The study was limited to a sample of 30 students from a single class, so its scope remains very narrow. Furthermore, since the sample was selected non-randomly—that is, based on specific criteria—the findings may not necessarily be applicable to student populations with different characteristics.

Therefore, recommendations for future research include implementing the flipped classroom-based e-LKPD on a larger scale and with a more heterogeneous student population. Additionally, future research could examine the application of the e-LKPD in other physics topics to assess the consistency of improvements in students' problem-solving abilities

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