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RESEARCH ARTICLE

Contextual Mobile Learning in Physics: Egrang-Based Digital Worksheets for Developing Critical Thinking Skills

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Abstract: This study analyzes the effectiveness of an Electronic Student Worksheet (E-LKPD) integrated with the local wisdom of the traditional egrang game in enhancing students' critical thinking skills in physics learning. The E-LKPD was developed using the ADDIE model (Analyze, Design, Develop, Implement, Evaluate) and tested with a one-group pretest–posttest design involving 35 students in Class XI A3. Effectiveness was measured through normalized gain (N-Gain) analysis of students' critical thinking test scores. Results showed an average N-Gain of 0.81 (high category), with 97% of students achieving substantial improvement. Integrating the egrang game as a contextual learning medium helped students link real-life experiences with physics concepts, fostering deeper understanding and active engagement. These findings indicate that the developed E-LKPD effectively improves critical thinking skills while supporting meaningful, culturally relevant, and student-centered learning aligned with 21st-century educational demands.

Keywords: mobile learning, digital worksheets, critical thinking skills, local wisdom, physics education, Egrang

1 Introduction

Twenty-first-century skills, particularly critical thinking, are essential competencies that must be fostered in the learning process to meet the challenges of globalization and rapid technological advancement (Afif et al., 2021; Efendi et al., 2023). In the context of physics learning at the senior high school level, critical thinking plays a crucial role in helping students understand and analyze complex physical phenomena and relate them to everyday life (Mellenia & Admoko, 2022). This ability enables students to analyze information, solve problems logically, and make well-informed decisions (Suarjana et al., 2020).

Several studies have shown that the Problem-Based Learning (PBL) approach can strengthen students' critical thinking skills (Papadakis, 2020; Papadakis, 2022). Nurjanah and Trimulyono (2022) found that a PBL-based E-LKPD is effective in developing critical thinking. This is consistent with the findings of Saputro and Rahayu (2020) and Khoiri et al. (2023), who reported that PBL encourages active student engagement in solving contextual problems while enhancing conceptual understanding and higher-order thinking. Syahidi et al. (2020) similarly affirmed that PBL is effective in cultivating critical thinking through authentic problem-solving activities.

The integration of local wisdom in learning has also been explored as a way to increase relevance and student engagement (Drolia et al., 2020; Drolia et al., 2022). Rumiati et al. (2021) showed that traditional games such as egrang (Indonesian stilts) can be integrated into physics education, since they embody scientific concepts such as work and energy. Egrang is a traditional game played using two wooden or bamboo poles with footrests attached, requiring players to maintain balance while walking. The concepts of work and energy are present when the player steps onto the stilts, begins moving, and eventually comes to a stop. The game originates from Lampung, where it is known as terompah pancung, and it is recognized by various names across Indonesia, such as ingkau (Bengkulu), tengkak-tengkak (Sumatra), and batungkau (South Kalimantan) (Rumiati et al., 2021).

Research by Nugraha and Deta (2023) and Anggreani (2021) also found that local wisdom can bridge students' understanding of physics content through contextual and meaningful experiences. Firnanda et al. (2024) and Sa'diyah et al. (2024) emphasized the importance of preserving culture through education, while Ariani (2020) argued that integrating local content into student worksheets (LKPD) can strengthen cultural identity and improve learning effectiveness. Avitrananda et al. (2020) further showed that LKPD based on local wisdom, when combined with the PBL model, significantly improves critical thinking skills. Based on the preliminary study and the results of the critical thinking test administered to Grade XI students of SMAN 2 Mojokerto, the findings are shown in Figure 1.

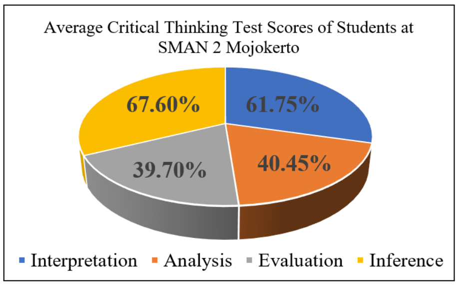


Figure 1 Average Percentage of Critical Thinking Test Scores

The results indicate that students' critical thinking skills in physics learning are still relatively low, particularly in the indicators of analysis and evaluation (Setyowati et al., 2011). This is largely due to the limited connection between physics content and students' real-life experiences (Azizah et al., 2021), as well as the inadequacy of textbooks, which mainly present theoretical concepts without contextual applications (Haryadi & Nurmala, 2021). In addition, the available learning media have not fully supported active and contextual engagement that enables students to meaningfully understand physics concepts (Papadakis et al., 2025; Zourmpakis et al., 2024).

From this explanation, it can be concluded that although many studies have examined the effectiveness of PBL and the integration of local wisdom separately, there remains a lack of research on developing PBL-based E-LKPDs integrated with local wisdom—particularly traditional egrang games—in the context of physics learning to enhance students' critical thinking skills. Therefore, the development of an E-LKPD that combines the PBL model with elements of local wisdom is essential to address the needs of 21st-century learning that is contextual, interactive, and meaningful.

The E-LKPD developed in this study integrates the cultural game of egrang, making the learning process more contextual and meaningful. It helps students grasp the concepts of work and energy through real-life activities in their surroundings while also fostering cultural appreciation. The inclusion of an instructional video on the egrang game, accessible directly within the E-LKPD, provides concrete visual stimuli that enhance students' interest and focus. Clear and systematic usage instructions support independent learning without confusion. The activities in the E-LKPD are designed according to Facione's critical thinking indicators, training students in critical and analytical thinking. A virtual lab feature using the PhET Energy Skate Park simulation further visualizes energy concepts interactively, even in the absence of a physical laboratory. Contextual problems based on real-world situations encourage students' decision-making abilities.

Accordingly, the objective of this research is to analyze the effectiveness of the egrang-integrated E-LKPD in improving senior high school students' critical thinking skills in the physics topic of work and energy. The novelty of this study lies in the development of a PBL-based E-LKPD integrated with the traditional egrang game. This integration provides a culturally relevant, student-centered, and digitally accessible worksheet to enhance critical thinking in physics, an approach not previously explored in physics education research.

2 Methods

2.1 Research Methods

This study employed a Research and Development (R&D) approach using the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation). R&D is a method aimed at producing a product and testing its effectiveness (Sugiyono, 2019). In this case, the product developed was an Electronic Student Worksheet (E-LKPD) integrated with the local wisdom of the egrang game on the topic of work and energy. The ADDIE model is a product development framework used to design instruction that supports complex learning processes (Branch, 2009). Its application emphasizes active, creative, and engaging learning (Dewi, 2018). (see Figure 2)

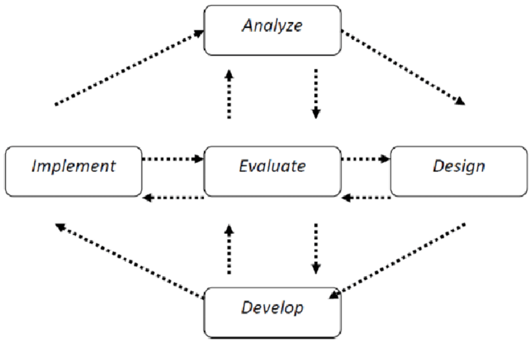


Figure 2 ADDIE Development Framework (Source: Angdala, 2007)

In the Analysis stage, the researchers identified students' low critical thinking scores and the lack of contextual learning media. In the Design stage, the storyboard for the E-LKPD was created based on PBL syntax and local wisdom content. The Development stage included media production and expert validation by two lecturers and one physics teacher. During the Implementation stage, a limited-scale trial was carried out in a Grade XI physics class. Finally, the Evaluation stage involved validation, revision, and pre–post testing to assess the product's effectiveness.

2.2 Limited Product Trial Method

This research was conducted in the Undergraduate Physics Education Program at Universitas Negeri Surabaya, with a limited-scale trial of the E-LKPD carried out during the even semester of the 2024/2025 academic year in Class XI A3 at SMAN 2 Mojokerto. The study employed a one-group pretest–posttest design, in which a single group received a pretest, treatment, and posttest. This design allowed for a direct comparison of students' scores before and after the intervention.

One-Group Pretest-Post test Design:

$$O_1 \longrightarrow X \longrightarrow O_2 \tag{1}$$

Here, X = Treatment given (use of the developed E-LKPD); O_1 = Pretest score (before treatment); O_2 = Posttest score class (after treatment).

The limited product trial was implemented using the Problem-Based Learning (PBL) model, which consists of five main steps: (1) orienting students to the problem through a video of the traditional egrang game to connect the concept of work and energy with real-life contexts; (2) organizing students into groups to discuss and identify problems presented in the E-LKPD; (3) guiding group discussions in completing interpretation and analysis tasks; (4) assisting students in independent and collaborative investigations through a virtual practicum using the PhET simulation on energy concepts; (5) guiding students to present and evaluate solutions through class discussions on evaluation and inference questions.

The product trial was conducted over two meetings. In the first meeting, students used E-LKPD 1, which focused on understanding the concepts of work and energy in the context of the egrang game through activities such as video observation, contextual discussion, solving problems, and drawing conclusions. In the second meeting, students used E-LKPD 2 to analyze the quantities in work and energy and their relationships through activities with the PhET virtual simulation. Students also connected the experimental results to determine effective strategies for playing egrang.

The teaching tools used included the E-LKPD, lesson module, student handouts, and the PhET simulation as a virtual laboratory. This structured implementation was designed to make physics learning contextual while simultaneously enhancing students' critical thinking skills.

2.3 Research Instruments

The research instruments consisted of pretests and posttests completed by students. The results of these tests were used to determine whether students' critical thinking skills had improved. The test items were adapted from Facione's (1990) critical thinking indicators, with modifications covering interpretation, analysis, evaluation, and inference. The data were analyzed quantitatively.

Table 1 presents the relationship between indicators, sub-indicators, sample items, and the scoring method:

Table 1 Mapping of Critical Thinking Indicators to Test Items

Indicator	Sub-Indicator	Sample Item (Contextual in Egrang)	Assessment Technique
Interpretation	Identifying and explaining relevant concepts	Students can describe data presented in a table to identify the player who performs the greatest amount of work based on appropriate calculations.	Scored 0–4 based on the accuracy of concept identification and clarity of explanation. Maximum score: 22
		Students can explain the essential meaning of a presented energy–time graph.	
Analysis	Differentiating arguments and identifying relationships	Students can analyze the work performed by an *egrang* player by considering the direction of displacement and the applied force.	Scored 0–4 based on the logical argument and correctness of the physics principle used.
		Students can analyze the concept of work and relate the work equation to the traditional *egrang* game.	
Evaluation	Assessing arguments and making valid judgments	Students can provide arguments about the influence of mass on work based on the work–energy theorem.	Maximum score: 22
		Students can evaluate arguments using the concepts of work and energy.	
Inference	Drawing conclusions from data and problems	Students can select the appropriate strategy for playing *egrang* according to the concepts of work and energy.	Scored 0–4 based on the depth of justification and the use of correct physics reasoning.
		Students can draw logical conclusions about the effect of changes in the mass of an *egrang* player on the work performed.	
Total Score			100

2.4 Data Analysis Techniques

The analysis included a normality test (Shapiro–Wilk), a paired-sample t-test, and an N-Gain calculation. Effectiveness was determined based on the percentage of students who achieved N-Gain scores in the medium and high categories. The E-LKPD was considered effective in enhancing students' critical thinking skills if the proportion of students with N-Gain scores (g) $\geq$ 0.30 fell within the medium to high category.

3 Results and Discussion

3.1 Product Development Results

The development of the *egrang*-integrated E-LKPD in this study was carried out systematically using the ADDIE model, which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation. Each stage played a crucial role in ensuring that the resulting E-LKPD was valid and effective in enhancing students' critical thinking skills. The following section provides a description and discussion of each stage in the ADDIE development process implemented in this research.

In the Analysis stage, the researchers collected data related to learning problems, which were then used to identify solutions through a needs analysis aligned with the issues found. This stage also involved examining the problems and needs related to improving students' critical thinking skills. The analysis phase served as the initial step in developing the E-LKPD integrated with *egrang* local wisdom.

In the Design stage, the researchers created the media design, including the cover, content layout, and student activities within the *egrang*-integrated E-LKPD. At this stage, learning tools and research instruments to be used in the learning process were also developed. The researchers designed and compiled the materials to be included in the physics E-LKPD integrated with the local wisdom of the traditional *egrang* game. These materials were structured using a contextual approach that connects physics phenomena to the concepts of work and energy transformation demonstrated in the traditional *egrang* game. The activities in the E-LKPD were designed to enhance critical thinking skills by referring to Facione's indicators—interpretation, analysis, evaluation, and inference. At this stage, the main components of the E-LKPD were also compiled. The storyboard of the developed E-LKPD is presented in Table 2.

Table 2 Storyboard of E-LKPD Development

No.	Scene	Explanation
1	Cover (Figure 3)	The cover was designed to include the title of the material, grade level, curriculum, author's name, and affiliation, and it features an image representing the local wisdom of the egrang game.
2	Identity (Figure 4)	It contains the activity name, class, group, and members' names.
3	Instructions and Objectives (Figure 5)	It contains guidelines for students while working on the E-LKPD, along with the objectives to be achieved after completing the activities.
E-LKPD ACTIVITY 1		
4	Cultural Insight (Figure 6)	It provides an explanation of the egrang game as a local wisdom topic that incorporates physics concepts.
5	Problem Orientation (Figure 7)	It contains a story about Si Bolang playing egrang, followed by questions on motion, force, potential energy, and kinetic energy.
6	Interpretation (Figure 8)	It presents interpretation questions based on observations of the egrang video, such as identifying the body parts involved, explaining the concept of work when the hands are straight, and applying its equation.
7	Analysis (Figure 9)	It contains questions on the types of energy in egrang, the calculation of work with opposing forces, forces at an angle, and the factors affecting the magnitude of work.
8	Evaluation (Figure 10)	It provides evaluation questions on the correctness of work concepts and asks students to justify their answers using the work formula.
9	Inference (Figure 11)	Students are asked to draw conclusions about the relationship between work and energy in the egrang game.
E-LKPD ACTIVITY 2		
10	Problem Orientation (Reasoning) (Figure 12)	It contains a story about Firda observing an egrang race, leading to questions on factors of energy transformation and strategies for winning the race.
11	Problem Formulation (Figure 13)	Based on Firda's story, students are asked to write appropriate problem formulations and discuss them with the teacher.
12	Activity Procedure (Figure 14)	This section presents steps for experiments using the PhET Energy Skate Park virtual lab, such as opening the simulation, setting variables, and recording data on kinetic, potential, and mechanical energy.
13	Interpretation (Experiment Variables) (Figure 15)	Students are asked to identify control, manipulated, and responding variables based on the problem formulation and activity procedure.
14	Experiment Table (Figure 16)	After conducting the experiment, students compile the data in the provided table.
15	Analysis (Figure 17)	Contains questions about the highest and lowest energy, analysis of the relationship between mass, speed, and height with kinetic and potential energy, and linking these to equations from the handout.
16	Evaluation (Figure 18)	Provides evaluation questions on the correctness of energy transformation statements and relates experiment results to strategies for winning the egrang game.
17	Inference (Figure 19)	Students draw conclusions from discussions and problem-solving as a reflection of their learning process.

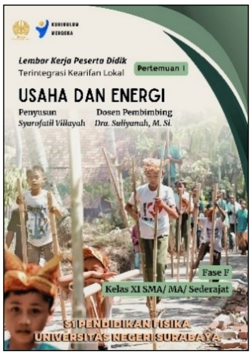


Figure 3 Cover

Figure 4 Identity

Figure 5 Instructions and Objectives

Figure 6 Cultural Insight

Figure 7 Problem Orientation

Figure 8 Interpretation

Figure 9 Analysis

Figure 10 Evaluation

Figure 11 Inference

Figure 12 Problem Orientation (Reasoning)

Figure 13 Problem Formulation

Figure 14 Activity Procedure

Figure 15 Interpretation (Experiment Variables)

Figure 16 Experiment Table

Figure 17 Analysis

Figure 18 Evaluation

Figure 19 Inference

This physics E-LKPD could be accessed through a Canva link shared by the teacher. Students used smartphones or computers connected to the school's internet. Learning with the E-LKPD was more effective when conducted synchronously, as it allowed students to discuss and understand the material more easily.

In the Development stage, the researchers created the E-LKPD based on the initial design. This stage involved producing the E-LKPD and assessing its validity. To ensure quality, the media was evaluated by two lecturers and one physics teacher using a validation sheet provided by the researchers, and revisions were made before classroom implementation.

In the Implementation stage, the researchers carried out a limited-scale trial of the developed E-LKPD during classroom learning activities. The product was tested to evaluate its effectiveness, which was assessed by comparing pretest and posttest scores, with the N-Gain score used as the indicator of improvement.

Within the ADDIE framework, evaluation is embedded at every stage to ensure the production of a high-quality and valid product. Evaluation was conducted both before and after classroom testing, beginning in the Analysis stage and continuing through the Design, Development, and Implementation stages.

3.2 Product Trial Results

The product trial aimed to evaluate the effectiveness of the developed *egrang*-based E-LKPD in improving students' critical thinking skills on the topic of work and energy. The results of the statistical analysis are summarized in Table 3, which presents the pretest and posttest descriptive statistics, t-test results, N-Gain, and effectiveness category.

Table 3 Results of the Statistical Analysis (n = 35)

Test	Mean	Sig.	T-value	P-value	N-gain	Effectiveness
Pretest	31.26	0.052	-38.39	0.000	0.81	97%
Posttest	86.63	0.845				

Note: Data follow a normal distribution indicates a significant increase between pretest and posttest.

The Shapiro–Wilk normality test indicated that both the pretest and posttest scores were normally distributed (sig. > 0.05), justifying the use of parametric analysis through a paired-sample t-test. Normality was further supported by the histogram and normal curve plots for both sets of scores. (see Figure 20)

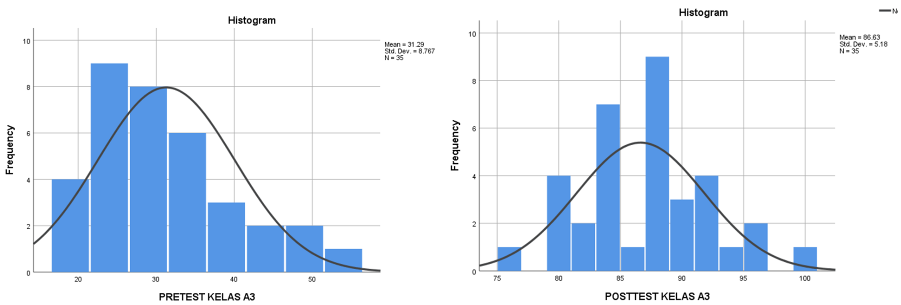
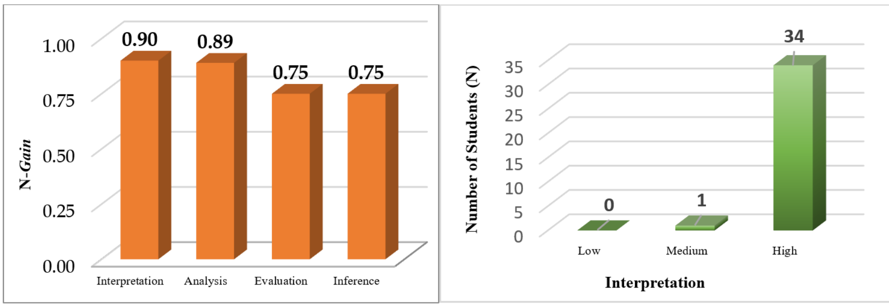


Figure 20 Histograms of Pretest-Posttest

Based on the pretest and posttest histograms, the score distributions in both measurements displayed a pattern that closely followed the normal curve, as indicated by the alignment of the histogram bars with the smooth bell-shaped curve overlay. In the pretest, the data distribution appeared relatively balanced around the central point, while in the posttest, the distribution maintained a symmetrical bell-shaped form. The visual agreement between the histogram and the normal curve supports the statistical normality test results, confirming that the data were normally distributed and suitable for parametric analysis.

The paired-sample t-test revealed a statistically significant difference between the pretest and posttest mean scores ($p < 0.05$), demonstrating that students' critical thinking skills improved after engaging with the E-LKPD.

The N-Gain analysis yielded an average score of 0.81, which falls within the high category according to Sugiyono's (2019) criteria. To further examine improvements across the critical thinking indicators, Figure 21(a) presents the results. As shown, the lowest improvement scores were found in the evaluation and inference indicators, both at 0.75, while the highest score was recorded in the interpretation indicator at 0.90. These results indicate that the N-Gain scores for all indicators were classified as high. Figure 21(b) presents the overall distribution of N-Gain scores.



(a) (b)

Figure 21 (a) N-Gain Score for Each Critical Thinking Indicator in Class XI A3; (b) Interpretation of N-Gain Scores for Class XI A3

Based on Figure 21(b), one student was in the medium category, while 34 students achieved high N-Gain scores. In this study, the effectiveness of the developed E-LKPD was evaluated based on the percentage of students achieving high N-Gain scores. Following Suhandi and Wibowo (2012), the E-LKPD is classified as highly effective because 97% of students achieved N-Gain $\geq$ 0.7. This high level of improvement suggests that combining PBL with local wisdom-based contextual learning fosters deeper conceptual understanding and encourages active student engagement.

The N-Gain score for the interpretation indicator was 0.90, categorized as high. This shows that the local wisdom–based E-LKPD effectively helped students interpret and connect contextual information, such as energy transformation graphs or velocity data from the egrang game. The improvement indicates that using the E-LKPD, which links physics concepts with traditional games, contributed positively to students' contextual understanding of meaning and relevance (Ennis, 1991). Visual and narrative support in the interpretation tasks also played a significant role in raising scores for this indicator, consistent with Susanta et al. (2023), who found that tasks designed with clear contexts can improve students' critical thinking skills.

For the analysis indicator, Class XI A3 achieved an N-Gain score of 0.89, also in the high category. This suggests that students were able to logically distinguish between facts and assumptions, for example, when analyzing force and displacement in the egrang game. This can be attributed to students' repeated practice with analytical problems during the learning process. Moreover, the E-LKPD strengthened the analysis of relationships between physics variables—such as force, displacement, and work—through the use of PhET virtual labs, enabling students to construct understanding through experimentation.

The evaluation indicator recorded the lowest N-Gain score, at 0.75 (still within the high category). This relatively lower result may reflect challenges in assessing the truth of arguments through physics-based reasoning. Some students struggled to provide scientifically accurate justifications in their answers. Although the E-LKPD included activities that encouraged students to evaluate arguments using scientific concepts, the lower scores suggest that more practice is needed in evaluating scientific statements and constructing systematic reasoning. This limitation highlights the need for future improvements, such as incorporating additional evaluative exercises based on arguments, case studies, or conceptual conflicts, to help students become more skilled at assessing arguments using evidence and physics principles.

The inference indicator also recorded an N-Gain of 0.75 (high category). This suggests that students were able to draw appropriate conclusions and strategies in playing egrang based on the physics concepts they had learned. The E-LKPD-based learning process improved students' ability to interpret and explain data in both tabular and graphical forms. However, the inference results also showed that some students still required further practice in constructing logical arguments and drawing accurate conclusions, especially when information was presented narratively and required elaboration through calculations. Learning with the E-LKPD integrated with the local wisdom of egrang helped students connect real-life experiences with scientific reasoning; nonetheless, their critical thinking skills still need to be strengthened through more varied training (Supriandi, 2023).

Overall, the N-Gain results of Class XI A3 demonstrate that the egrang-integrated E-LKPD effectively supported students in building conceptual understanding of the topic, making the learning process more meaningful (Aprianti et al., 2024). The integration of traditional egrang games into the E-LKPD provided relevant context for understanding physics concepts while reinforcing local cultural values (Putri et al., 2023). This aligns with 21st-century learning principles, which emphasize developing critical thinking skills through student-centered and real-world problem-based learning (Muliana et al., 2024).

The analysis also revealed that one student remained in the medium category, suggesting that this student may not have fully benefited from the E-LKPD. Possible factors include:
(1) Lack of focus during classroom learning;
(2) Carelessness in understanding and completing tasks;
(3) Unfamiliarity with problem-based learning combined with local wisdom contexts.

Critical thinking skills vary among individuals and may be influenced by internal factors such as learning motivation, prior knowledge, physical condition, and habits (Aisy & Ardhana, 2023; Ni'mah et al., 2025). Furthermore, critical thinking needs to be cultivated from an early stage so that it becomes habitual in students' thought processes (Dini et al., 2025).

According to Suhandi and Wibowo (2012), the effectiveness of a learning medium can be determined by the percentage of students who obtain N-Gain scores in the high category. In this research, 34 out of 35 students achieved high N-Gain scores, yielding 97%, which falls into the high effectiveness category.

These findings demonstrate that the implemented learning process was effective in enhancing students' critical thinking skills, showing that the E-LKPD integrated with egrang local wisdom successfully facilitated more meaningful comprehension of the material and encouraged active participation. This is consistent with Prastowo (2011), who argued that contextually designed learning media help students build stronger conceptual understanding and increase motivation, ultimately improving learning outcomes.

In addition, integrating local wisdom with mobile learning environments fosters critical thinking through contextualized problem solving. The traditional egrang game provided authentic experiences that, when combined with mobile accessibility, enabled students to analyze, infer, and evaluate within familiar cultural contexts. This finding aligns with Papadakis et al. (2023), who emphasized that mobile-based smart technologies and simulations enhance open learning by supporting active engagement, real-time feedback, and collaborative critical thinking. Papadakis et al. (2023) also highlighted that integrating cloud technologies and augmented reality can further strengthen student engagement, interactivity, and learning effectiveness in digital and mobile learning environments. Thus, integrating cultural contexts such as the egrang game with mobile-based learning and advanced digital technologies can make learning activities more meaningful, interactive, and relevant to students' lives while simultaneously developing their 21st-century skills, particularly critical thinking in STEM education.

Although the findings indicate high effectiveness, this study has several limitations. The scope of the research was restricted to one school and one class, so the results cannot be generalized to a broader population. In addition, the evaluation indicator received the lowest scores, suggesting that further development is needed in this section of the E-LKPD to optimize outcomes. Considering these limitations, future research should examine the effectiveness of other E-LKPDs based on local wisdom in different physics topics, with particular attention to activities related to students' critical thinking skills, especially in evaluation.

4 Conclusion

The findings of this research demonstrate that the E-LKPD integrated with *egrang* local wisdom was highly effective in enhancing students' critical thinking skills. This is evidenced by the high average N-Gain score of 0.81 in Class XI A3, with 97% of students achieving scores in the high category. Each critical thinking indicator also fell within the high effectiveness range. The integration of traditional *egrang* games into physics learning provided a meaningful, contextualized environment that helped students connect real-life experiences with scientific reasoning. Although a small portion of students showed lower improvement, possibly due to internal factors such as motivation or unfamiliarity with the learning approach, the overall results confirm that the developed E-LKPD effectively supports student engagement, conceptual understanding, and critical thinking development. This aligns with 21st-century learning principles that emphasize contextual, student-centered, and problem-based instruction.

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Conflict of Interest

The authors declare that they no have conflict of interest.

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