Volume 10 Number 2, August 2025, pp. 274-283
P-ISSN:2477-7935
E-ISSN: 2548-6225
DOI: 10.59052/edufisika.v10i2.45973

ENHANCING CRITICAL THINKING SKILL THROUGH STEM E-LKPD ASSISTED BY LIVEWORKSHEETS ON ADVANCED CLARIFICATION INDICATORS

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Article Info
Received: 23 June 2025
Accepted: 11 August 2025
Publication: 26 August 2025

Abstract :
Students' ability to think critically, particularly in terms of providing advanced clarification, is still relatively low. Therefore, innovative learning media are needed to encourage the development of these skills. This study aims to analyze the effectiveness of STEM-based Student Worksheets (LKPD) assisted by liveworksheets in improving students' critical thinking skills in physics learning. These LKPD are designed by integrating the Engineering Design Process (EDP) stages of the STEM approach. The study employed a quantitative approach with a one-group pretest-posttest design. The research subjects consisted of 33 students from Class X-1 of SMA Negeri 5 Banda Aceh, selected through purposive sampling. The research instrument consisted of an essay question designed to measure students' critical thinking skills, which were analyzed using the Shapiro-Wilk normality test, N-Gain test, and Wilcoxon Signed-Rank test. The analysis results showed a significant increase after the intervention, with an average N-Gain of 0.94, which falls into the high category, and a significance value of 0.000 (<0.05). These findings suggest that the integration of STEM-based E-LKPD with a live worksheet is an effective and contextual learning strategy for developing students' critical thinking skills.

Keywords: Critical Thinking Skill, Physics Learning, STEM Approach,

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INTRODUCTION

Rapid developments in technology, information, communication, and science in the 21st century have brought new challenges that demand changes in the world of education. Alenezi (2019) explains that 21st-century education has shifted from a teacher-centered learning model to a more learner-oriented approach. In this context, teaching methods increasingly emphasize a constructivist approach, where the teacher's role shifts to that of a facilitator who guides the learning process, rather than simply conveying information directly. The classroom environment is structured in such a way that students have control over their learning process (Daodu et al., 2024; Orak and Al-Khresheh, 2021). As a result of these changes, Sulistyanto et al. (2020) emphasize that there are seven key skills that students must master, one of which is the ability to think critically in solving problems. Critical thinking is not just a skill, but also reflects how a person views and responds to various issues. This ability requires

individuals to be open-minded, highly curious, and willing to accept and consider other perspectives, even when faced with more substantial evidence, and to be prepared to change their beliefs. To cultivate critical thinking skills, individuals need to be involved in activities that demand the ability to analyze, integrate, evaluate, and apply information deeply (Dad & Akbar, 2023).

Critical thinking skills are very important for students to have. Ridho et al. (2020) state that this ability can help students in dealing with everyday problems. However, based on data from the Program for International Student Assessment (PISA) from 2008 to 2018, it shows that the critical thinking skills of Indonesian students are still relatively low, ranking 64th out of 65 countries (Afifah & Agoestanto, 2020). Previous studies also reinforce this finding, stating that students' critical thinking skills are still in the non-critical category, particularly in the indicator of providing advanced clarification (Nurjannah et al., 2022; Akwantin et al., 2022; Putri et al., 2023; Ramdani et al., 2020). The low achievement on these indicators is often caused by students' lack of understanding of the material, which impacts their ability to formulate logical and in-depth answers (Najaah et al., 2020).

Indicators that provide advanced clarification are a crucial aspect of critical thinking, reflecting a person's ability to explore and analyze information in depth, rather than merely on a superficial level. According to Ennis (1962) this indicator consists of three main sub-indicators, namely defining, considering a definition, and identifying assumptions. The ability to define involves the accuracy with which students explain the meaning of a concept or term scientifically. Evaluating a definition indicates the extent to which students can assess the clarity and appropriateness of a definition in a particular context. Meanwhile, identifying assumptions relates to students' ability to recognize statements that are accepted without direct evidence in an argument or problem-solving process. These three abilities complement each other and form a crucial foundation for developing strong conceptual understanding and the ability to present arguments logically throughout the learning process.

To develop students' critical thinking skills in providing advanced clarification, innovative learning approaches are needed that meet the demands of the 21st century. One approach that is considered effective in developing these skills is the STEM approach (Permanasari, 2016). STEM integrates science, technology, engineering, and mathematics into the learning process, enabling students to apply academic concepts to solve real-life problems (Syukri et al., 2021). By combining these four disciplines in education, the STEM approach can enhance 21st-century skills. A STEM-based learning environment provides students with hands-on experiences, enabling them to develop understanding independently through a learner-centered approach (Hacıoğlu, 2021; Mariano & Chiappe, 2021). The STEM approach integrates the Engineering Design Process (EDP), which enables students to integrate scientific and mathematical investigations into practical applications by designing, building, testing, and refining prototypes to address the problems they face. This process not only encourages students to draw on their life experiences and explore ideas creatively through experimentation and literacy, but also fosters a learning environment that supports collaboration and critical thinking (Koumara et al., 2024; Siew, 2022; Sudrajat et al., 2022). There are various types of models that can be used as EDP; this study integrates five EDP steps into the learning process: ask, imagine, plan, create, and improve (Syukri and Ernawati, 2020).

The STEM approach is not limited to classroom learning strategies alone, but can also be applied in learning media such as Student Worksheets (LKPD). The integration of STEM in the LKPD allows students to connect academic concepts with real-life experiences, while honing their critical thinking skills (Ratu et al., 2022). This aligns with the view that critical thinking skills can be developed during the learning process through the STEM approach (Noperman, 2024). Research conducted by Lestari et al. (2018) demonstrates that STEM-based LKPD has a significant positive impact on students' critical thinking skills. LKPD is one type of teaching material that plays a significant role in supporting the success of learning activities. However, research by Prabowo (2021) shows that in practice, students often adopt a passive attitude when completing tasks assigned by teachers and lack enthusiasm in working on LKPD. This situation causes many students not to complete the assigned tasks. Therefore, innovation in the form of digital technology, namely the Electronic Student Worksheets (E-LKPD), is needed to enhance student engagement and promote more effective and engaging learning processes. One platform supporting the development of interactive E-LKPD is Liveworksheets, a website that enables the creation of e-worksheets online. This platform streamlines the process of designing interactive and engaging learning tools, allowing students to complete worksheets directly online (Lisnuriyanih, 2021; Rohmah, 2022). In addition, liveworksheets are ideal for use in STEM approaches

that emphasize exploratory and participatory processes. This platform facilitates interactive learning through dynamic worksheets that enable the integration of multimedia elements, including images, videos, and audio. These features not only enhance student engagement but also encourage active exploration, problem-solving, and discovery learning (Prihandono et al., 2023; Apriani et al., 2024). With its ability to present material in an engaging and interactive manner, liveworksheets have the potential to cultivate students' critical thinking skills (Susanti et al., 2023).

Research conducted by Prihandono et al. (2023) revealed that E-LKPD based on live worksheets with the Problem-Based Learning (PBL) model was able to improve students' critical thinking skills, with an N-Gain value of 0.531, which is classified as moderate. However, the study has not fully adopted a learning approach that aligns with the needs of the 21st century. This aligns with the findings of Arifanti et al. (2021), who stated that most LKPD currently in use have not yet integrated more modern and relevant learning approaches. The modern and relevant learning approach referred to in the context of 21st-century education refers to a model that encourages active, creative, and collaborative student engagement. Therefore, innovation is needed in the development of STEM-based E-LKPD that aligns with current demands, to optimize the use of digital media in supporting the development of students' critical thinking skills, particularly in providing advanced clarification.

Based on these issues, there is a need to develop and implement STEM-based Electronic Student Worksheets (E-LKPD) integrated with the liveworksheets platform as a strategy to improve students' critical thinking skills, particularly in terms of providing advanced clarification. This study aims to analyze the effectiveness of this learning media in the context of physics learning.

RESEARCH METHOD

Research Design

This study applied a quantitative approach and was categorized as a pre-experimental study with a one-group pretest-posttest design. The research was conducted at SMA Negeri 5 Banda Aceh in the second semester of 2024/2025, from January 13 to February 3, 2025.

Research Target/Subject

This study involved one class as the research subject. All tenth-grade students at SMA Negeri 5 Banda Aceh were included in this study. Sample selection was conducted using purposive sampling techniques. Thus, Class X-1, with 33 students, was chosen as the research sample.

Research Procedure

The research procedure was systematically structured to ensure a scientific, measurable, and goal-oriented process aimed at evaluating the effectiveness of STEM-based E-LKPD assisted by the Liveworksheets platform in enhancing students' critical thinking skills, particularly in providing advanced clarification. The process began with an extensive literature review to establish a strong theoretical foundation, followed by preliminary observations to identify real challenges in the classroom. Based on these findings, research instruments in the form of critical thinking test items were developed and subsequently validated by experts to ensure accuracy and reliability before being employed in the field.

Subsequent stages involved administering a pretest to measure students' initial abilities, implementing the learning intervention using STEM-based E-LKPD, and conducting a posttest to assess improvements in critical thinking skills. The collected data were then analyzed systematically to determine the effectiveness of the intervention, and the findings were critically discussed by integrating theoretical perspectives and previous empirical studies. The final stage involved drawing comprehensive conclusions and formulating recommendations to guide future research and instructional practices.

Instruments and Data Collection Techniques

The instrument used in this study was an essay test designed to measure students' critical thinking skills, particularly in terms of providing advanced clarification based on the critical thinking skills indicators developed by Ennis (1962). The type of data collected was quantitative data in the form of students' pretest and posttest scores after completing the test instrument.

The test consists of five essay questions tailored to the context of the Renewable Energy material. The question format emphasizes the context of projects that students have worked on, thereby encouraging

the development of argumentative and logical reasoning in line with STEM-based learning. Instrument validation procedures were conducted through expert testing by two validators who are lecturers in the field of physics education and learning media development. Validation was conducted by assessing the content, construction, and language aspects using a 1–4 rating scale. The validation results showed that the instrument was in the "valid" category and suitable for use with minor revisions. Meanwhile, the instrument's reliability results indicated that it fell into the reliable category.

Data collection techniques were conducted in two stages: pretest and posttest. The pretest was administered before the learning intervention to measure students' initial ability to provide advanced clarification. The posttest was administered after the intervention to measure improvements in students' abilities following learning with the STEM-based E-LKPD using live worksheets.

Data Analysis Technique

The data in this study were analyzed using IBM SPSS Statistics software version 26.0. The initial stage of analysis began with the Shapiro–Wilk normality test to identify whether the pretest and posttest data obtained were normally distributed. Next, the improvement in student ability was analyzed by calculating N-Gain to measure the magnitude of the increase in scores following the treatment. Finally, hypothesis testing was conducted using the Wilcoxon Signed-Rank test, which aimed to test the significance of the difference between pretest and posttest scores after learning with STEM-based E-LKPD assisted by liveworksheets.

RESULTS AND DISCUSSION

This study involved two stages of data collection, focusing on renewable energy materials to assess students' critical thinking skills, particularly in terms of providing advanced clarification, both before and after the treatment. The researcher acted directly as the teacher and was assisted by the physics teacher of class X-1 during the learning process. Before the learning activity began, students were first given a pretest to measure their initial abilities. Next, the treatment was administered through learning using STEM-based Electronic Student Worksheets (E-LKPD) combined with the liveworksheets platform. Before further statistical analysis was conducted, the pretest and post-test data were tested for normality using the Shapiro-Wilk test. The table below shows the results of the data normality analysis.

Table 1. Results of normality test analysis

Test Type	Shapiro-Wilk			Conclusion
	Statistic	df	Sig.	
Pretest	.714	33	<.001	Non-normal
Posttest	.431	33	<.001	Non-normal

After conducting the normality test, the analysis stage continued with the N-Gain test to assess the extent of improvement in students' critical thinking skills before and after the intervention was implemented. Details of the students' pretest and posttest average scores are presented in the following table.

Table 2. Analysis of student improvement provides advanced clarification

Test Type	Min	Maks	X	N-gain	Category
Pretest	0	50	30	0,94	High
Posttest	75	100	96		

The table above shows that the average N-gain score was 0.94, indicating a high gain index category. The average pretest score obtained by students was 30, and their critical thinking skills improved by 95% after receiving treatment in the form of STEM-based E-LKPD learning assisted by live worksheets, with an average posttest score of 96, which falls into the high improvement category. This difference is also illustrated visually in the chart in Figure 1.

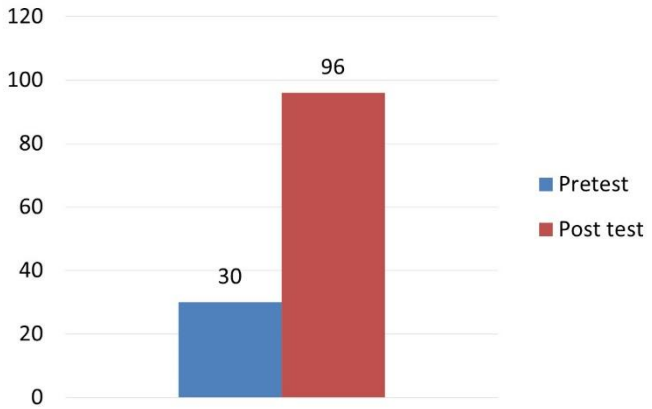

Figure 1. The pretest and posttest results of students' abilities provide advanced clarification

The figure above shows that after analysis, the indicator provided an advanced increase of 96, which is classified as high. Referring to the normality test results in Table 1, it is known that the research data is not normally distributed. Therefore, hypothesis testing was conducted using a nonparametric technique, the Wilcoxon Signed-Rank Test. This test was used to assess the effectiveness of STEM-based E-LKPD assisted by liveworksheets in improving students' critical thinking skills, particularly in the aspect of advanced clarification in physics learning. The analysis results show that:

Table 3. Results of the hypothesis test for the indicator of providing advanced clarification

Indicator	Pretest - Posttest	
	Z	Asymp. Sig. (2-tailed)
Providing advanced clarification	-5.114	.000

Referring to the results of the Wilcoxon Signed Ranks test shown in the previous table, a Z value of -5.114 was obtained with a significance of 0.000 < 0.05. These results indicate a significant difference between the students' pretest and posttest scores. Thus, it can be concluded that the use of STEM-based E-LKPD, integrated with live worksheets, is effective in improving students' critical thinking skills, particularly in the advanced clarification indicator. After participating in the learning process, students demonstrated improved ability in defining the physics concepts they had learned, considering various alternative solutions conceptually, and identifying the assumptions underlying the projects they were working on.

In this study, students were given the freedom to plan learning activities, design and implement projects, and produce products (Annisa et al., 2019; Priantari et al., 2020), thereby making a significant contribution to the development of their critical thinking skills, particularly in terms of providing advanced clarification. Project-based activities not only enrich students' conceptual understanding but also train their critical thinking skills in identifying assumptions and providing in-depth explanations. This aligns with the findings of Herlina et al. (2022) and Kahar and Ili (2022), who explain that project-based learning provides a more meaningful and memorable learning experience for students. Through the application of the project-based learning model, students are challenged to demonstrate a high level of creativity in completing projects, thereby encouraging them to explore and develop their critical thinking skills more deeply. The pretest and posttest questions designed to measure the ability to provide an advanced clarification indicator in the study were adapted to the context of the project students were working on, allowing them to provide more logical and argumentative answers. These adjustments not only increased the relevance of the questions to students' learning experiences but also contributed to the improvement of the achievement results on this indicator, as seen in Table 2.

This finding is in line with the results of research by Ramdani et al. (2020), which showed that the ability to provide an advanced clarification indicator obtained the highest score compared to other indicators. This is thought to be because the material related to this indicator has often been conveyed by teachers in the learning process, so that students become more familiar and are able to remember and

process information more effectively. However, different results were shown by Ardiyansah et al. (2024), who found that the application of the project-based learning model actually resulted in the highest increase in the indicator of providing elementary clarification, while the indicator of providing advanced clarification only experienced an increase in the moderate category. This difference suggests that the implementation strategy has a significant influence on the effectiveness of developing critical thinking indicators, the focus of the learning approach, and the type of media used. In addition, Miswari et al. (2020) emphasized that the ability to provide advanced clarification can only be built through reflection activities on conclusions made based on contextual facts obtained through learning experiences. This reflective process encourages students to reject assumptions that are not in accordance with the theory and develop valid conclusions, as well as form strong definitions based on the knowledge they already have.

Project-Based Learning (PBL) is a learning model that begins with problems as the starting point, followed by a project as the final solution. This model aims to develop critical thinking skills, creativity, innovation, and increase students' active involvement in learning (Hidayat, 2021). A number of studies have also shown that this learning model is effective in improving students' critical thinking skills (Sholeh et al., 2024). In its application, PjBL encourages students to play an active role and think creatively throughout the learning process. The teacher functions as a facilitator who guides the course of activities, provides direction during the process, and assesses the results of the projects that students work on (Putri, 2023). In line with the learning needs of the 21st century, the Project-Based Learning (PBL) model has been integrated with the STEM approach to provide a more comprehensive and integrated learning experience. The collaboration between the multidisciplinary STEM approach and PjBL, which presents authentic and contextual learning experiences through projects, forms an effective synergy in improving the quality of the learning process (Tanto et al., 2025). In addition, STEM-based PjBL also challenges and encourages student motivation, because it can train them to think critically, conduct in-depth analysis, and develop higher-order thinking skills in a more structured manner (Asri et al., 2021).

The STEM-based PjBL model is an instructional approach that encourages students' active involvement at every stage of learning, encouraging them to think creatively and participate actively. This model requires students to be actively involved, both individually and in group work. Through such collaboration, students are encouraged to conduct investigations to solve problems, build an understanding of the core lessons from the project findings, and integrate the knowledge gained into various disciplines such as science, technology, engineering, and mathematics (Astuti et al., 2019; Kanza et al., 2020). The STEM approach can encourage students to explore their curiosity in understanding the material while instilling responsibility for the learning process they undergo. This condition indirectly facilitates students' involvement in critical thinking processes (Khoiriyyah et al., 2022; Novitasari et al., 2022). During the learning process, the implementation of indicators provides advanced clarification supported by the implementation of the plan, and improves the stages of EDP integrated into the E-LKPD used. The plan stage focuses on planning solutions through systematic project design. At this stage, students are trained to think critically when selecting and considering the best solutions, ensuring that the developed project remains consistent with theory and relevant to the problems faced. If the product created by students does not function according to its intended principles, they must undergo an improvement stage to redesign it. The improvement stage allows students to deepen their understanding of STEM integration as a basis for product development (Rahimi & Kim, 2021). In this process, students are trained to think critically by identifying assumptions about the shortcomings of the product that has been made, then making improvements to meet the established criteria (Sapphira & Sari, 2024).

The STEM-based E-LKPD used in this study utilizes the liveworksheets platform, which facilitates interactive, flexible, and multimodal learning. By using liveworksheets, E-LKPD not only contains text and images, but also audio, direct links to additional learning resources, and instructional videos. This can support students' more profound understanding of the material and encourage them to engage with it actively. Therefore, (Susanti et al., 2023) state that liveworksheets are a potential medium for developing critical thinking skills.

The development of STEM-based E-LKPDs assisted by liveworksheets in this study is expected to address the challenges of 21st-century learning that are still rarely integrated into E-LKPDs. This media is designed with a progressive approach, adaptive to technological developments, and oriented towards strengthening students' critical thinking skills, especially in the indicator of providing advanced

clarification. However, in the implementation process, it still has limitations. One of them is the dependence on digital facilities, such as the availability of devices and internet connections. Therefore, for wider implementation, adequate infrastructure support and teacher training in designing digital LKPD that are aligned with the STEM approach are needed.

CONCLUSION

The findings of this study indicate that the use of STEM-based E-LKPD, integrated with the Liveworksheets platform, is effective in improving students' critical thinking skills, particularly in terms of advanced clarification. This effectiveness is evidenced by the achievement of an N-Gain score of 0.94 in the high category, as well as the results of the Wilcoxon Signed Ranks Test, which yielded a significance value of 0.000 (< 0.05), indicating a significant improvement following the implementation of the intervention. The integration of the STEM approach with live worksheets in physics education, particularly through project-based activities and stages in the Engineering Design Process (EDP), provides a contextual and meaningful learning experience. This encourages students to think critically, identify assumptions, and construct logical and in-depth explanations. Based on these findings, it is recommended that future research develop STEM-based E-LKPDs with a focus on other critical thinking skill indicators and test them at different educational levels over a more extended period to observe the long-term impact on overall critical thinking skill improvement.

ACKNOWLEDGMENTS

The author expresses gratitude to Allah SWT for His abundant mercy, guidance, and blessings, which have enabled this research to be completed successfully. The author would like to express gratitude to the Dean of the Faculty of Teacher Training and Education at Syiah Kuala University for all the support provided during the research process. The author also appreciates the Principal of SMA Negeri 5 Banda Aceh, the teachers, and all the students of class X-1 for their permission, assistance, and active participation in the implementation of this research. The author hopes that the results of this research will contribute positively to the world of education, particularly in developing learning strategies that foster students' critical thinking skills.

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