

ASSURE-BASED STUDENT WORKSHEETS WITH A STEM APPROACH TO IMPROVE CRITICAL THINKING SKILLS ON RENEWABLE ENERGY

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Abstract :

This study aimed to develop an ASSURE-based STEM-oriented Student Worksheet on renewable energy and to examine its validity, readability, and effectiveness in improving students' critical thinking skills. The study employed a Research and Development (R&D) method using the ADDIE development model and a quasi-experimental nonequivalent control group design. Product validity was evaluated through expert validation, readability was assessed using a cloze test, and effectiveness was determined by analyzing the improvement in students' critical thinking skills based on pretest and posttest results. The developed student worksheet demonstrated very high validity (Aiken's $V = 0.93$) and high readability (97%). Its implementation significantly improved students' critical thinking skills, as reflected by a higher N-Gain in the experimental group (0.72) than in the control group (0.55), with the Independent Samples t-test confirming a significant difference between the two groups ($p < 0.05$). This study introduces an ASSURE-based STEM-oriented student worksheet on renewable energy to improve students' critical thinking skills. Overall, the developed student worksheet was highly valid, easy to understand, and effective in enhancing students' critical thinking skills. Therefore, it has the potential to support the implementation of student-centered physics learning.

Keywords: Worksheet, ASSURE, STEM

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INTRODUCTION

The rapid advancement of science and technology in the twenty-first century requires students to develop a range of competencies needed to adapt to increasingly complex global challenges (Sartika & Kau, 2025). One of the essential competencies emphasized in twenty-first-century education is critical thinking, which is recognized as one of the four core competencies (4Cs), alongside creativity, collaboration, and communication (Annisa et al., 2023). Critical thinking involves not only understanding information but also analyzing problems, evaluating evidence logically, and making well-reasoned decisions (Kholilah et al., 2024; Trilling & Fadel, 2009). In line with Indonesia's educational policy, the Graduate Competency Profile (Dimensi Profil Lulusan/DPL) identifies critical thinking as one of the key competencies that should be developed through classroom instruction.

Therefore, learning should not merely emphasize conceptual understanding but should also foster students' ability to think critically when addressing real-life problems.

Physics plays a crucial role in developing students' critical thinking skills because it explores natural phenomena closely related to everyday life and technological development. Physics learning requires students not only to understand scientific concepts but also to explain phenomena, analyze relationships among concepts, evaluate scientific evidence, and solve problems through logical reasoning (Trilling & Fadel, 2009). However, these competencies do not develop automatically and must be fostered through well-designed, student-centered learning experiences. Previous studies have shown that students' critical thinking skills in physics remain underdeveloped. Azizah & Aslamiah (2025) reported that students were insufficiently engaged in classroom activities, limiting the development of their critical thinking skills. Similarly, Kholilah et al. (2024) found that students experienced difficulties in analyzing information and constructing scientific arguments. These findings indicate the need for instructional innovations that provide meaningful learning experiences while encouraging active student participation.

The effectiveness of learning is influenced not only by instructional content but also by the instructional model implemented by teachers. One instructional model that supports systematic lesson planning is the ASSURE model. This model guides teachers through a sequence of instructional design processes, including analyzing learner characteristics, stating learning objectives, selecting instructional methods and media, utilizing instructional materials, encouraging active learner participation, and evaluating learning outcomes (Jingga et al., 2023; Malia et al., 2023). Previous studies have demonstrated the effectiveness of the ASSURE model in improving instructional quality. Zahran (2023) reported that the ASSURE model enhanced instructional effectiveness, whereas (Arifin et al., 2024) found that it improved students' learning motivation, participation, and academic achievement. Furthermore, Purwanto et al., (2022) suggested that the systematic integration of instructional media through the ASSURE model contributes to the development of students' critical thinking skills. These findings indicate that the ASSURE model provides a systematic framework for instructional planning; however, its application has mainly focused on improving general learning outcomes rather than integrating interdisciplinary learning approaches such as STEM.

Another instructional approach that has received considerable attention is the Science, Technology, Engineering, and Mathematics (STEM) approach. STEM integrates concepts from science, technology, engineering, and mathematics into meaningful learning experiences, enabling students to solve authentic problems encountered in everyday life (Oktaviana & Haryadi, 2020). Integrated STEM combines science, technology, engineering, and mathematics within a unified learning activity, enabling students to apply scientific concepts through problem-solving, engineering design, and mathematical reasoning in authentic contexts (Yulianti, 2024). Previous research has consistently demonstrated that STEM-based learning enhances students' critical thinking through inquiry, problem-solving, and evidence-based decision-making activities (Aydin et al., 2024). (Angela & Rahayu, 2022) also reported that STEM learning encourages students to explore multiple alternative solutions to complex problems. Compared with the ASSURE model, which emphasizes systematic instructional design, the STEM approach primarily focuses on interdisciplinary problem-solving and authentic learning experiences. These complementary characteristics suggest that integrating both approaches may provide a more comprehensive learning framework for fostering students' critical thinking skills.

The successful implementation of the ASSURE model and the STEM approach requires appropriate instructional materials capable of facilitating systematic learning activities. One such instructional material is a student worksheet. A student worksheet serves as a learning guide that enables students to construct conceptual understanding through investigation, discussion, and problem-solving activities (Yufa et al., 2024). The effectiveness of a student worksheet depends on the quality of its content, presentation, and learning activities (Ketaren, 2022). Munawaroh & Budijastuti (2024) further reported that systematically developed student worksheets improve students' learning motivation, academic achievement, and critical thinking skills. Therefore, developing a student worksheet that integrates the ASSURE model and the STEM approach is expected to support more meaningful physics learning aligned with the demands of twenty-first-century education.

Previous studies have developed instructional materials based on either the ASSURE model or the STEM approach. Although both approaches have demonstrated positive effects on learning, they have generally been implemented separately and have mainly focused on learning outcomes, motivation, or instructional effectiveness. Few studies have integrated the ASSURE model and the STEM approach into a student worksheet for renewable energy learning while simultaneously evaluating its validity, readability, and effectiveness in improving students' critical thinking skills. Consequently, a research gap remains in developing instructional materials that combine systematic instructional design with interdisciplinary learning to foster critical thinking skills. The novelty of this study lies in integrating the ASSURE instructional model and the STEM approach into every learning activity of the student worksheet, enabling instruction to be tailored to students' characteristics, oriented toward contextual problem-solving, and systematically facilitating the development of critical thinking skills.

Based on the foregoing, this study aims to develop an ASSURE-based student worksheet integrated with the STEM approach, evaluate its validity and readability, and examine its effectiveness in improving the critical thinking skills of tenth-grade students at SMA Negeri 6 Semarang.

RESEARCH METHOD

Research Design

This study employed a Research and Development (R&D) method using the ADDIE instructional design model, which consists of five phases: Analysis, Design, Development, Implementation, and Evaluation (Branch & Varank, 2009). The product developed in this study was an ASSURE-based STEM-oriented Student Worksheet on renewable energy for tenth-grade senior high school students to improve their critical thinking skills. The stages of the ADDIE model adopted in this study are presented in Figure 1.

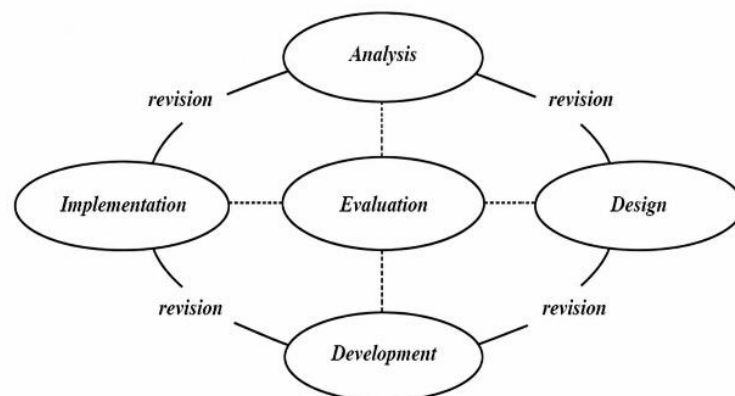


Figure 1. The ADDIE development model (adapted from Branch, 2009).

Research Target/Subject

This study was conducted at SMA Negeri 6 Semarang during the 2025/2026 academic year. The research population consisted of all tenth-grade students. A purposive sampling technique was employed to select the research sample. This technique was chosen because the selected classes met the predetermined criteria, including the implementation of the renewable energy topic in the tenth-grade curriculum, comparable learning characteristics, and the identified need to improve students' critical thinking skills. Accordingly, Class X-D was assigned as the experimental group and Class X-C as the control group.

The selection of these classes was based on several considerations. First, renewable energy is included in the tenth-grade physics curriculum, making the students suitable participants for implementing the developed ASSURE-based STEM-oriented student worksheet. Second, preliminary classroom observations and interviews with the physics teacher indicated that students' critical thinking skills in analyzing and solving physics problems were still relatively low. In addition, physics instruction was predominantly teacher-centered and relied on conventional worksheets that had not

been specifically designed to foster critical thinking skills. Therefore, these classes were considered appropriate for evaluating the effectiveness of the developed student worksheet.

Prior to data collection, permission to conduct the research was obtained from the Faculty of Mathematics and Natural Sciences, Universitas Negeri Semarang, and SMA Negeri 6 Semarang. All participants were informed about the purpose of the study, and the collected data were used solely for research purposes while maintaining the confidentiality of their information.

Research Procedure

The analysis phase aimed to identify instructional needs, students' characteristics, and problems encountered during physics learning. Classroom observations and interviews with a physics teacher at SMA Negeri 6 Semarang were conducted during this phase. The findings revealed that students' critical thinking skills in analyzing and solving physics problems were relatively low. Furthermore, the worksheets used in the classroom were mainly adapted from textbooks and had not incorporated either the ASSURE instructional model or the STEM approach, particularly in renewable energy learning. Curriculum requirements, learning objectives, instructional materials, and students' characteristics were also analyzed to establish the specifications of the worksheet to be developed.

During the design phase, the prototype of the ASSURE-based STEM-oriented student worksheet was prepared based on the results of the needs analysis. This phase involved formulating learning objectives, identifying critical thinking indicators, designing learning activities according to the ASSURE instructional model integrated with the STEM approach, preparing assessment instruments, and developing the worksheet layout. All components were systematically designed to support student-centered learning and facilitate the development of critical thinking skills.

In the development phase, the student worksheet was produced and subsequently validated by three physics education lecturers and two experienced physics teachers. The validation covered four aspects: content, presentation, language, and graphical design. Feedback provided by the validators was used to revise and improve the product. After revision, the readability of the student worksheet was evaluated through a cloze test involving 36 eleventh-grade students (Class XI-A). A small-group trial involving 10 tenth-grade students (Class X-A) was then conducted to obtain preliminary information regarding the practicality of the developed worksheet.

The implementation phase was conducted to evaluate the effectiveness of the developed student worksheet in classroom learning. The experimental group learned using the ASSURE-based STEM-oriented student worksheet, whereas the control group received instruction using the conventional learning materials employed by the school. Students' critical thinking skills were assessed through pretest and posttest administration.

Evaluation was conducted continuously throughout all phases of the ADDIE model. This stage involved analyzing the results of expert validation, readability testing, and classroom implementation to determine whether the developed student worksheet satisfied the criteria of validity, readability, and effectiveness before being recommended as a physics learning resource.

Instruments, and Data Collection Techniques

The research instruments consisted of student worksheet validation sheets, research instrument validation sheets, a cloze test, and a critical thinking skills test. The validation sheets were used to evaluate the validity of the developed student worksheet in terms of content, language, presentation, and graphical design. The research instrument validation sheets were used to assess the appropriateness of the test items in terms of content validity, construct validity, language clarity, and alignment with the learning objectives. The cloze test was employed to assess the readability of the worksheet, while the critical thinking skills test measured students' improvement after the implementation of the ASSURE-based STEM-oriented student worksheet. The critical thinking test consisted of essay questions designed to measure students' abilities in interpretation, analysis, inference, evaluation, and explanation.

Before implementation, all research instruments were validated by five expert validators, consisting of three physics education lecturers and two experienced physics teachers, to ensure their alignment with the research objectives, learning outcomes, critical thinking indicators, and renewable

energy content. The critical thinking test was subsequently examined for item validity, reliability, item difficulty, and discrimination index before being administered to the participants.

Data Analysis Technique

The collected data were analyzed to determine the validity, readability, and effectiveness of the developed student worksheet. The validity of the student worksheet and the research instruments was analyzed based on expert judgment conducted by three physics education lecturers and two physics teachers. The validation data were analyzed using Aiken's V index with the assistance of Microsoft Excel, following the procedure proposed by Aiken (1985). The instruments were considered valid if the Aiken's V coefficient met the minimum acceptable value ($V \geq 0.80$).

The readability level of the student worksheet was analyzed using the cloze test to determine students' level of comprehension of the developed student worksheet. The test results were calculated as percentages and interpreted according to the readability criteria proposed by Sugiyono (2023).

All inferential statistical analyses were performed using IBM SPSS Statistics 26. Prior to hypothesis testing, the data were subjected to prerequisite tests, including the Shapiro–Wilk normality test and Levene's homogeneity test. Since the data satisfied the assumptions of normality and homogeneity, and the objective of the study was to compare the posttest mean scores of two independent groups, the Independent Samples *t*-test was employed at a significance level of 0.05. This analysis was selected because the objective of the study was to determine whether there was a significant difference in students' critical thinking skills after the implementation of the ASSURE-based STEM-oriented student worksheet. The effectiveness of the developed student worksheet was further evaluated using the normalized gain (N-Gain) based on the criteria proposed by Hake (1998).

RESULTS AND DISCUSSION

Characteristics of the ASSURE-Based STEM-Oriented Student Worksheet

The development results indicate that the designed student worksheet is characterized by the integration of the ASSURE instructional model syntax with the Science, Technology, Engineering, and Mathematics (STEM) approach in the topic of renewable energy. This characteristic is reflected in the learning activities, which follow the six stages of the ASSURE model: analyze learners, state Objectives, Select Methods, Media, and Materials, Utilize Media and Materials, Require Learner Participation, and Evaluate and Revise. This integration was designed to ensure that the learning process is systematic, student-centered, and capable of facilitating the development of students' critical thinking skills.

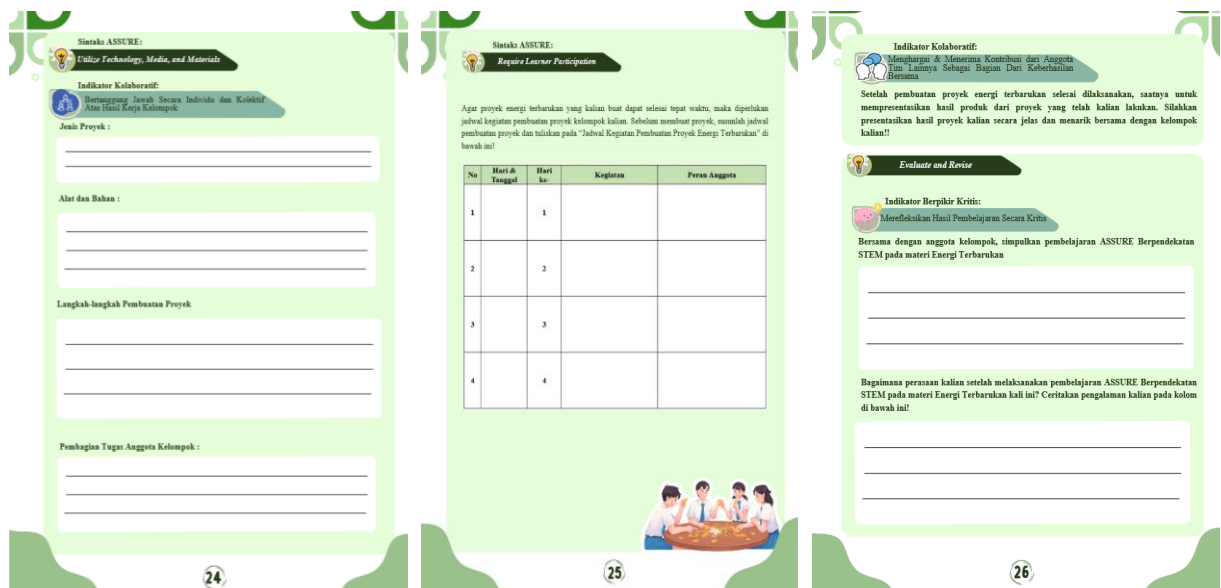
The implementation of the ASSURE model syntax in the student worksheet was organized according to the characteristics of each learning stage. Each stage not only guides students to understand renewable energy concepts but also actively engages them in analysis, discussion, and reflection, thereby creating more meaningful learning experiences. The implementation of the ASSURE model syntax in the student worksheet is presented in Figure 2.



(a) Analyze learners stage

(b) State standards objectives stage

(c) Select methods, media and material stage



(d) Utilize technology, media and material stage

(e) Require learner participation stage

(f) Evaluate and revise stage

Figure 2. (a) (b) (c) (d) (e) (f) Implementation of the ASSURE model syntax in the student worksheet

As shown in Figure 2, the analyze learner stage is implemented through contextual phenomena designed to explore students' prior knowledge of renewable energy. The state objectives stage presents the learning objectives to be achieved during the instructional process. The Select Methods, media, and materials and utilize media and materials stages are implemented through the use of various learning resources, including instructional materials, illustrations, and QR code-based learning videos to support conceptual understanding. Furthermore, the require learner participation stage is implemented through group discussions, case analyses, and project-based activities, while the evaluate and revise stage is carried out through learning evaluation and reflection activities. The integration of these six stages actively engages students throughout the learning process in accordance with the characteristics of the ASSURE instructional model.

In addition to integrating the ASSURE model syntax, the student worksheet also incorporates the STEM approach into every learning activity. The STEM approach was designed to provide students with contextual learning experiences through the integration of Science, Technology, Engineering, and Mathematics in solving renewable energy-related problems. The implementation of the STEM approach in the student worksheet is presented in Figure 3.



Figure 3. (a) (b) (c) (d) Integration of STEM components in the student worksheet

As illustrated in Figure 3, the Science component is implemented through activities that require students to identify and analyze renewable energy concepts based on the contextual phenomena presented. The Technology component is incorporated through the use of digital learning resources, such as QR code-based instructional videos and information searches from various sources. The Engineering component is reflected in activities requiring students to design simple solutions to renewable energy problems, while the mathematics component is integrated through calculation, data analysis, and interpretation of investigation results. The integration of these four components provides students with meaningful learning experiences by enabling them not only to understand theoretical

concepts but also to apply them to authentic problem-solving situations. The student worksheet also explicitly facilitates the development of critical thinking skills, as illustrated in Figure 4.



Figure 4. (a) (b) (c) Learning activities facilitating critical thinking skills

The student worksheet explicitly promotes the development of critical thinking skills based on the indicators proposed by Trilling & Fadel (2009). Learning activities begin with the presentation of contextual information and renewable energy-related phenomena that encourage students to analyze information, evaluate evidence, and relate scientific concepts to real-life situations (Figure 4a). Subsequently, students are guided to integrate scientific, technological, and engineering concepts through the analysis of electric vehicles as one application of renewable energy. In this activity, students are required to connect various sources of information, evaluate the benefits and challenges of electric vehicle implementation, and construct evidence-based arguments (Figure 4b). Furthermore, students participate in identifying problems within their surrounding environment and proposing alternative solutions based on the utilization of renewable energy resources. This activity encourages students to formulate questions, analyze multiple alternatives, and determine the most appropriate solution to contextual problems (Figure 4c). Overall, these learning activities were systematically designed to foster critical thinking skills through information analysis, evidence evaluation, argument construction, decision-making, and problem-solving processes aligned with the ASSURE instructional model and the STEM approach.

Validity of the Developed

The validation results indicated that the developed ASSURE-based STEM-oriented student worksheet achieved a very valid category, as presented in Table 1.

Table 1. Aiken's V coefficient results

Aspect	Aiken's V	Category
Content	0,87	Very Valid
Presentation	0,92	Very Valid
Language	0,98	Very Valid
Graphics	0,93	Very Valid
Average	0,93	Very Valid

As shown in Table 1, all assessment aspects obtained Aiken's V coefficients above 0.80, indicating that the developed student worksheet fulfilled the validity criteria and was appropriate for physics learning. The high validity score resulted from the systematic development process that integrated the ASSURE instructional model with the STEM approach throughout the learning

activities. From the content aspect, the materials were aligned with the learning outcomes, accurately represented renewable energy concepts, and accommodated critical thinking and collaborative learning indicators through investigation and problem-solving activities. Previous studies have reported that the alignment between instructional materials, learning objectives, and competency indicators contributes to conceptual understanding and higher-order thinking skills Kholilah et al. (2024) while scientifically accurate materials support meaningful conceptual learning (Novriani et al., 2021).

Regarding presentation, the student worksheet was organized systematically from the introduction to the closing activities and followed the learning sequence of the ASSURE model integrated with the STEM approach. A well-structured presentation enables students to understand learning objectives more easily and participate actively in learning activities (Suryaningsih & Sri Rahayu, 2020). The inclusion of discussion tasks, work instructions, illustrations, and supporting media further promotes student engagement (Derta et al., 2023; Putri & Astawan, 2022).

The language aspect obtained the highest validity score because the student worksheet employed clear, communicative, and grammatically appropriate language accompanied by explicit instructions. The use of language that matches students' characteristics enhances readability and facilitates conceptual understanding (Asmaryadi et al., 2022; Oktarina et al., 2023). Similarly, the high score in the graphical aspect indicates that the student worksheet was designed according to good visual design principles, including appropriate typography, layout, color combinations, illustrations, and overall visual presentation. Attractive graphical design not only increases students' learning motivation but also facilitates conceptual understanding (Fany et al., 2025; Hardiansyah et al., 2022). This finding is consistent with Wea et al. (2025) who reported that well-designed worksheets enhance students' learning activities. Overall, these findings demonstrate that the developed ASSURE-based STEM-oriented student worksheet satisfies all validity requirements as a learning resource. This result supports the findings of Munawaroh et al. (2024) who concluded that systematically developed worksheets fulfill the content, presentation, language, and graphical validity criteria.

Readability of the Student Worksheet

The readability test using the cloze test method is presented in Table 2.

Table 2. Student worksheet readability test results

Respondents	Average percentage	Category
36 Grade XI students of SMA Negeri 6 Semarang	97%	Easy to Understand

The readability test showed that the developed ASSURE-based STEM-oriented student worksheet obtained an average readability score of 97%, indicating that it was easy to understand. This result suggests that students were able to comprehend the worksheet content effectively in terms of language use, information presentation, and activity instructions. The high readability score can be attributed to the use of communicative language, systematic content organization, and clear learning instructions, enabling students to follow each stage of the learning activities with ease. These findings are consistent with Ketaren (2022), who emphasized that worksheet readability is influenced by language suitability, content organization, and learning activities. Similar findings were also reported by Setianingrum & Nurohman (2022) and (Pieper et al., 2021), (Ardyati et al., 2025), who found that communicative language and systematic presentation improve students' understanding of instructional materials.

Improvement of Students' Critical Thinking Skills

Students' critical thinking skills were evaluated using pretest and posttest scores based on the seven critical thinking indicators proposed by Trilling and Fadel (2009). The average scores for each indicator are presented in Figure 5.

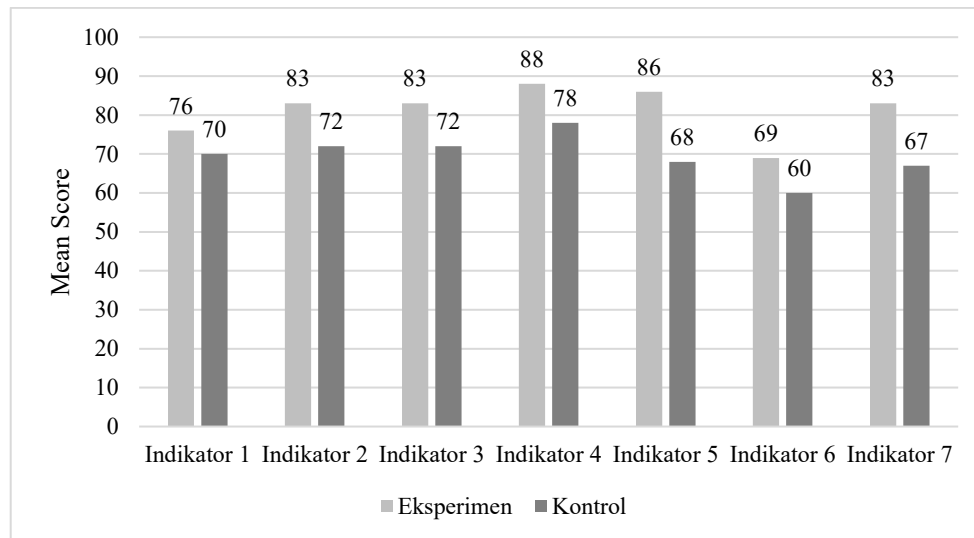


Figure 5. Average pre-test and post-test scores of critical thinking skills

Notes:

- Indicator 1 : Providing effective reasoning
- Indicator 2 : Analyzing parts of information
- Indicator 3 : Analyzing and evaluating evidence, arguments, and perspectives
- Indicator 4 : Synthesizing and connecting information
- Indicator 5 : Interpreting information and drawing conclusions based on analysis
- Indicator 6 : Critically reflecting on the learning process
- Indicator 7 : Identifying questions to determine the best solution

As illustrated in Figure 5, all critical thinking indicators in the experimental class showed greater improvement than those in the control class. Before hypothesis testing, the data satisfied the prerequisite assumptions of normality and homogeneity ($p > 0,05$). Therefore, an Independent Samples t-test was conducted (Nuryadi et al., 2017).

Table 3. Normality test results

Class	Statistic	df	Sig.
Experimental pre-test	.963	36	.258
Experimental post-test	.953	36	.131
Control pre-test	.946	36	.078
Control post-test	.977	36	.649

Source: SPSS

Based on the normality test results presented in Table 3, the pretest and posttest scores of students' critical thinking skills in both the experimental and control classes were normally distributed. This is indicated by the Shapiro Wilk significance values, all of which were greater than 0.05 ($p > 0.05$). Therefore, the data satisfied the normality assumption, allowing the analysis to proceed with the homogeneity test. The results of the homogeneity test are presented in Table 4.

Table 4. Homogeneity test results

Data	Levene Statistic	df1	df2	Sig.
Pretest Scores	1.974	1	70	.164
Posttest Scores	.001	1	70	.971

Source: SPSS

As shown in Table 4, the variances of the critical thinking scores between the experimental and control classes were homogeneous, as indicated by significance values greater than 0.05 ($p > 0.05$). Since both the normality and homogeneity assumptions were satisfied, an Independent Samples t-test was conducted. The results are presented in Table 5.

Table 5. Independent samples t-test results

Variable	Levene Sig.	t	df	Sig. (2-tailed)
Critical thinking skills	.971	4.796	70	.000

Source: SPSS

The Independent Samples *t*-test results presented in Table 5 indicate a significant difference in posttest scores between the experimental and control classes. This is evidenced by the significance value (Sig. 2-tailed) of less than 0.05 ($p < 0.05$). These findings indicate that the use of the ASSURE-based STEM-integrated student worksheet resulted in a significant improvement in students' critical thinking skills compared with conventional instruction. To further examine the magnitude of the improvement, the normalized gain (N-Gain) scores for both classes were calculated. The results are presented in Table 6.

Table 6. N-Gain analysis of students' critical thinking skills

Class	Mean score		N-Gain	Category
	Pre-test	Post-test		
Experimental	32	81	0,72	High
Control	30	70	0,55	Moderate

Based figure 5, all indicators of critical thinking skills in the experimental class showed greater improvement than those in the control class. This improvement indicates that the ASSURE-based Student Worksheet with a STEM approach effectively facilitated students in providing logical reasoning, analyzing and evaluating information, connecting various concepts, drawing conclusions based on analysis, reflecting on the learning process, and determining solutions to contextual problems. These findings are further supported by the N-Gain analysis presented in Table 6, which demonstrates that the ASSURE-based Student Worksheet with a STEM approach was effective in improving students' critical thinking skills. The improvement was supported by learning activities that integrated the stages of the ASSURE model with the STEM approach through problem analysis, group discussions, investigations, and contextual problem-solving, thereby encouraging students to actively participate in the learning process.

This finding is consistent with Yulianti & Masiroh (2024) who reported that STEM-based physics learning promotes students' active engagement in problem-solving activities, thereby supporting the development of higher-order thinking skills. Reflective activities also encouraged students to evaluate their learning processes and experiences, utilize feedback to improve their learning strategies, and enhance the quality of self-reflection (Brandmo et al., 2020; Pieper et al., 2021). These findings are also consistent with Yulianti & Masiroh (2024) who stated that STEM-based Student Worksheets effectively develop critical thinking skills through activities involving analysis, evaluation, and conclusion drawing. Similar results were reported by Yulianti & Anjani (2020) who found that STEM integration in learning encourages students to provide logical reasoning, evaluate information based on evidence, and draw accurate conclusions. In addition Huda et al. (2025) reported that STEM-based Student Worksheets are effective in developing students' critical thinking skills through problem-solving activities. The present findings are further supported by Yulianti et al. (2023) who demonstrated that digital media-assisted physics learning with a STEM approach contributes to the development of 21st-century skills, particularly critical thinking, collaboration, and problem-solving skills.

Overall, the improvement in students' critical thinking skills indicates that integrating the ASSURE model with the STEM approach into the Student Worksheet effectively facilitates the development of critical thinking through systematic, contextual, and student-centered learning activities. Therefore, the developed ASSURE-based Student Worksheet with a STEM approach can serve as an effective alternative instructional material for physics learning on renewable energy to enhance students' critical thinking skills.

Educationally, these findings imply that the ASSURE-based STEM-oriented student worksheet can serve as an effective instructional resource for promoting student-centered physics learning. By integrating the systematic stages of the ASSURE instructional model with contextual STEM activities, the worksheet provides teachers with a structured framework to facilitate inquiry,

collaboration, problem-solving, and critical thinking in renewable energy learning. The developed worksheet may also support the implementation of the Merdeka Curriculum by encouraging active student participation and fostering essential 21st-century skills, particularly critical thinking, communication, collaboration, and problem-solving. Therefore, the worksheet can be considered a practical learning resource for physics teachers seeking to enhance students' higher-order thinking skills through contextual and technology-supported learning

CONCLUSION

This study concludes that the ASSURE-based STEM-integrated student worksheet on renewable energy achieved a high level of validity and high readability, indicating that it is appropriate for use in physics learning. The implementation of the student worksheet was also proven effective in improving students' critical thinking skills, as evidenced by the significant difference in post-test scores between the experimental and control classes and the high N-Gain score obtained by the experimental class. These findings demonstrate that integrating the ASSURE instructional model with the STEM approach into the student worksheet effectively facilitates the development of students' critical thinking skills through systematic, contextual, and student-centered learning activities.

For classroom implementation, physics teachers are encouraged to integrate the developed student worksheet into renewable energy learning by facilitating collaborative discussions, problem-solving activities, and contextual STEM-based investigations that actively engage students in the learning process. Teachers are also encouraged to adapt the worksheet to students' learning characteristics and available classroom resources to maximize its effectiveness.

Future studies are recommended to implement the ASSURE-based STEM-integrated student worksheet in other physics topics, educational levels, and school settings using larger and more diverse samples to improve the generalizability of the findings. In addition, future research may investigate its long-term impact on students' critical thinking skills and examine its effectiveness in enhancing other 21st-century skills, such as communication, creativity, collaboration, and problem-solving, as well as its integration with digital learning technologies

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