

Advancing critical thinking through SDGs 7-oriented interactive STEM media in elementary education

Melinda Mu'aadzah^{1*}, Jajang Bayu Kelana², Faridillah Fahmi Nurfurqon³
^{1,2,3} PGSD, IKIP Siliwangi, Indonesia

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Abstract

Elementary school students' critical thinking skills remain low due to a lack of active engagement and minimal use of interactive learning media and instructional models, resulting in difficulties in comprehending subject matter, analyzing problems, and drawing logical conclusions. This study aims to develop SDGs 7-based interactive media integrated with STEM learning to improve students' critical thinking skills. The interactive media contextually addresses the issue of clean and affordable energy sustainability in alignment with real-world problems. This study employed a Research and Development (R&D) method using the ADDIE model. Implementation followed a one-group pretest-posttest design conducted in two stages: a limited trial involving 34 Grade V-B students and a broad trial involving 67 Grade V-A and V-C students at SDN Utama Mandiri 1, Cimahi City. Data collection techniques included interviews, media expert and content expert validation sheets, pretest-posttest instruments, and student response questionnaires. Validation results indicated that the media was rated as highly feasible, with scores of 95% from the media expert and 82% from the content expert. The paired sample t-test revealed a significant difference between pretest and posttest scores in both the limited and broad trials ($p = 0.000 < 0.05$). Furthermore, N-Gain analysis showed a moderate improvement in critical thinking skills, with a score of 0.42 in the limited trial and 0.63 in the broad trial. Student responses toward the media were categorized as excellent. These findings suggest that the SDGs 7-based interactive media developed is feasible for use and has the potential to support the improvement of elementary school students' critical thinking skills.



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*Corresponding Author:

Melinda Mu'aadzah
PGSD, IKIP Siliwangi
Email Author: melinameyy22@gmail.com

INTRODUCTION

Critical thinking refers to students' ability to analyze and resolve problems encountered in daily life. According to Ennis (2011), critical thinking is the ability to

engage in skilled reflection and rational reasoning when making decisions or solving problems. In line with 21st-century developments, there is a growing urgency to enhance students' higher-order cognitive skills, such as problem-solving, problem analysis, creative thinking, and sound decision-making (Nuraeni et al., 2019). As learners, students must develop critical thinking skills to navigate the demands of the 21st century, as these skills serve as a foundational asset to meet the challenges of contemporary development (Cynthia & Sihotang, 2023).

In reality, however, the critical thinking skills of Indonesian elementary school students remain relatively low, as evidenced by their limited active participation in the learning process (Zulaika et al., 2022; Rahim, 2023). This is consistent with initial observations and interviews conducted with a Grade V teacher at SDN Utama Mandiri 1 in Cimahi City, which revealed that students' critical thinking skills still need to be improved. The teacher indicated that the majority of students struggle to analyze problems, articulate logical reasoning, and draw conclusions. Students tend to become easily bored and lack motivation during lessons, which negatively impacts their willingness to express their opinions. This situation is believed to stem from instruction that remains dominated by lecture-based methods and video presentations without the support of interactive learning strategies, thereby depriving students of meaningful learning experiences and opportunities to develop higher-order thinking skills. This finding is further supported by Nailinda et al. (2023), who demonstrated that students' critical thinking skills are still low, particularly in analyzing problems and drawing logical conclusions, due to the conventional and rote-learning-oriented nature of instruction, which hinders the optimal development of higher-order thinking skills. Non-interactive teaching methods that are disconnected from real-life contexts can impede students' ability to comprehend learning material (Nurfurqon et al., 2024).

Given these challenges, it is necessary to seek alternative approaches through the use of more engaging and interactive instructional models and media that can enhance students' critical thinking skills. Teachers should continually seek, design, and implement varied strategies to foster students' interest and enthusiasm for learning (Maulani et al., 2022). Teachers' creativity and variety play a crucial role in determining the instructional models employed and in influencing students' motivation to achieve learning objectives (Febiwanti et al., 2023). In this regard, STEM (Science, Technology, Engineering, and Mathematics) learning is considered an appropriate solution to address these issues. According to Faizah and Septiana (2021), STEM learning trains learners to develop character through the integration of science, technology, engineering, and mathematics. Through this process, students are trained to think logically, analyze problems, and make sound decisions, thereby fostering the development of critical thinking skills (Setiadi, 2011). Previous research has shown that STEM learning has the potential to enhance students' critical thinking skills through problem-based learning activities and scientific exploration (Thibaut et al., 2018; Bybee, 2013; Kelana et al., 2025).

One applicable solution is the use of instructional media. According to Magdalena et al. (2021), the use of media has been found to influence the learning process in the classroom by assisting teachers in delivering subject matter and by creating an active, innovative, creative, critical, and enjoyable learning atmosphere. The use of instructional media must be varied through the development of the latest innovations, particularly in light of the rapid advancement of technology. Therefore, the proposed design involves the development of digital-based interactive media to improve the quality of learning and sharpen students' thinking skills. The use of digital-based interactive media enhances students' digital skills while supporting flexible, efficient, and contemporary learning (Fitriah & Khotimah, 2025). Previous studies have shown that interactive media is considered highly feasible and effective, and contributes significantly to improving student motivation and learning outcomes through more engaging instructional presentation, thereby enhancing the quality of the learning process (Wulandari et al., 2022; Iskandar et al., 2023).

These findings indicate that both STEM learning and interactive media have the potential to support the development of students' critical thinking skills. However, research that integrates STEM learning and interactive media in the context of SDGs at the elementary school level remains relatively limited, despite the importance of SDGs integration in fostering students' awareness of sustainability issues from an early age. There is therefore a need to develop learning that combines both approaches to support critical thinking skills as well as students' understanding of sustainability issues. The Sustainable Development Goals (SDGs) are global development goals aimed at creating a balance between social, economic, and environmental dimensions to ensure a better life for present and future generations (Aziz & Najicha, 2024; Widiatmoko et al., 2024). Furthermore, research specifically developing SDGs-based interactive learning media in STEM instruction at the elementary level remains relatively scarce, particularly that focusing on SDGs Goal 7, which concerns clean and affordable energy. This goal emphasizes the use of environmentally friendly and sustainable energy, making it relevant for contextual learning in elementary schools. The integration of SDGs 7 in learning is not only intended to enhance students' cognitive abilities, but also to cultivate individuals capable of analyzing problems, evaluating information, and proposing logical solutions in addressing sustainability challenges (Kelana et al., 2024). The novelty of this study therefore lies in the integration of SDGs 7-based interactive media with STEM learning to improve the critical thinking skills of elementary school students through more contextual and sustainability-oriented instruction.

Based on the background described above, the researchers conducted this study by focusing on the development of SDGs 7-based interactive media through a STEM learning approach, entitled "Advancing critical thinking through SDGs 7-oriented interactive STEM media in elementary education." This study aims to develop Canva-based interactive learning media designed to enhance students' critical thinking skills, addressing the following research questions: (1) How is the development process of SDGs 7-based interactive media with STEM learning carried out? (2) How is the

feasibility of the developed interactive media determined? (3) How does its use influence and how effective is it in supporting learning? and (4) What constraints are encountered during the learning process?

METHOD

This study employed a Research and Development (R&D) method aimed at developing a product in the form of SDGs 7-based interactive media supported by STEM learning. Research and Development is a research method used to produce a specific product and to test the effectiveness of that product (Rustandi & Rismayanti, 2021). To produce a specific educational product, needs analysis of students is conducted alongside testing of product effectiveness to ensure it can function effectively for both learners and the wider community (Sugiyono, 2015). The research procedure follows the ADDIE development model, which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation (Putra & Dahlan, 2022; Vivie et al., 2021; Rachma et al., 2023). The ADDIE model was selected because of its systematic and structured stages, which facilitate researchers in developing instructional media step by step from needs analysis to product evaluation (Pradana & Wahyudi, 2025).

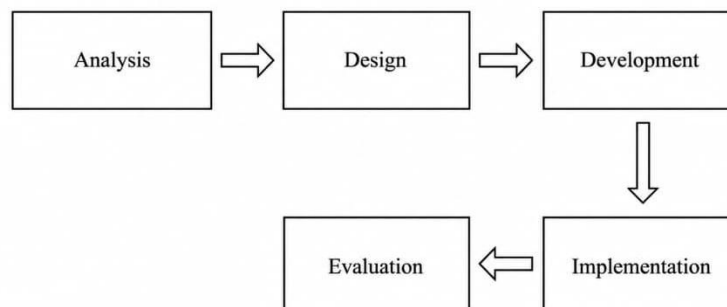


Figure 1. ADDIE Research Procedure

The research subjects were Grade V students at SDN Utama Mandiri 1, Cimahi City, Indonesia. In the limited trial, 34 Grade V-B students participated, consisting of 20 male and 14 female students. In the broad trial, 67 Grade V-A and V-C students participated, consisting of 38 male and 29 female students. A one-group pretest-posttest experimental design was used, measuring students' critical thinking skills before (pretest) and after (posttest) receiving treatment in the form of SDGs 7-based interactive media supported by STEM learning. This design was used to determine the degree of improvement in students' critical thinking skills after the use of the instructional media. The critical thinking indicators applied were: identifying problems, collecting and analyzing information, drawing logical conclusions, providing reasoning, and determining solutions (Ennis, 1996).

The research instruments included: (1) interview sheets for needs analysis; (2) media expert and content expert validation sheets to assess product feasibility; (3) pretest and posttest items to measure students' critical thinking skills; and (4) student response questionnaires to obtain feedback and identify challenges in using the instructional media. Interviews were conducted with a Grade V teacher to identify

learning problems and media development needs. Instrument validity was established through content validity assessment by content and media experts. An instrument was considered valid if it met the feasibility criteria based on expert evaluation in the "feasible" or "highly feasible" category.

The data analysis techniques used in this study included both qualitative and quantitative approaches. Qualitative data analysis was conducted through the stages of data collection, data reduction, data presentation, and conclusion drawing. Quantitative data analysis was performed using IBM SPSS Statistics for Windows version 26 and Microsoft Excel, encompassing normality tests, paired sample t-tests, and N-Gain calculations to assess improvements in students' critical thinking skills.

RESULT AND DISCUSSION

Result

The development study was conducted at SDN Utama Mandiri 1, Cimahi City, Indonesia. The product developed by the researchers was an SDGs 7-based interactive learning medium supported by STEM learning. The research findings are described according to the stages of the ADDIE model in correspondence with the research questions.

Interactive Media Development Process






The interactive media development process followed the ADDIE model stages: Analysis, Design, Development, Implementation, and Evaluation. The first stage was Analysis, during which a needs analysis was carried out concerning the state of Natural Science and Social Studies (IPAS) learning, the use of instructional media, and the challenges encountered by teachers. Interviews with the Grade V classroom teacher were also conducted to identify teacher needs for developing SDGs 7-based interactive media supported by STEM learning to foster students' critical thinking skills. The analysis results revealed that instruction was still dominated by lecture-based methods and the use of instructional videos without interactive learning media. Moreover, students experienced difficulties in comprehending subject matter in depth, analyzing problems, and drawing logical conclusions.

The second stage was Design, during which an initial product draft of the interactive media was developed based on the initial needs analysis and a literature review. This initial draft began with the creation of a storyboard, the development of learning outcomes and objectives, and the development of content and materials integrating SDGs 7. The interactive media design utilized the Canva application and its available features. The third stage was Development, during which the interactive media was developed in accordance with the planning draft previously created. Once the interactive media was completed and approved through supervisory guidance, validation was conducted by a media expert and a content expert.

The fourth stage was Implementation, during which the revised interactive media product was subjected to a trial through a limited trial and a broad trial to determine

the influence of its use and the product's effectiveness, using pretest and posttest instruments. The fifth and final stage was Evaluation, during which all assessment results were processed and conclusions were drawn regarding the quality of the developed instructional media. The following are the interactive media products developed based on SDGs 7 supported by STEM learning.

Table 1. Interactive Media Product

Page / Component	Description
 <p data-bbox="405 781 486 815">Cover</p>	<p>The cover features images relevant to the topics discussed in the interactive media, namely energy and its utilization. The color scheme and illustrations were selected in accordance with the characteristics of Grade V elementary school students.</p>
 <p data-bbox="320 1126 569 1160">STEM Stages Page</p>	<p>The STEM learning design page presents the stages of learning activities, from problem identification to presenting project results. The design is organized systematically in accordance with the STEM model, with color choices and illustrations adapted to the characteristics of Grade V elementary school students to make it engaging and comprehensible.</p>
  <p data-bbox="336 1697 553 1731">Discussion Page</p>	<p>The discussion page presents stimulus questions and STEM-stage questions to foster students' critical thinking skills and connect energy-related material to everyday life. These activities are designed to encourage active discussion and the expression of students' ideas.</p>
 <p data-bbox="309 1982 584 2016">Self-Reflection Page</p>	<p>The self-reflection activity page invites students to evaluate their comprehension and learning experiences, as well as to identify difficulties and successes encountered during the learning process.</p>

Feasibility of the Interactive Media

Product feasibility was assessed based on the validation conducted by a media expert and a content expert. Media validation was performed by a lecturer with expertise in educational technology and instructional media development, while content validation was conducted by a lecturer with competence in elementary education and curriculum development. Media expert validation covered aspects of visual appearance, readability and clarity, appropriateness of illustrations and visual elements, animation and transitions, navigation and interactivity, audio-visual components, language and readability, and ease of use. Content expert validation covered aspects of alignment with learning outcomes, quality and accuracy of content, appropriateness for learner characteristics, presentation of content, development of 21st-century skills, engaging quality of the content, and language and readability. The expert validation results are presented in the following table.

Table 2. Expert Validation Results

Expert Validation	Percentage	Category
Media Expert	95%	Highly Feasible
Content Expert	82%	Highly Feasible

The feasibility rating obtained from the media expert validation was 84 points, categorized as "highly feasible" with a percentage of 95%, with a note that the media is feasible for use following revisions based on the media expert's suggestions. The suggested revision involved increasing the font size of the title to be larger than the font size of the body content. The feasibility rating obtained from the content expert validation was 59 points, categorized as "highly feasible" with a percentage of 82%, with no revisions required.

Influence and Effectiveness of the Interactive Media

The influence and effectiveness of the interactive media's use in this study were measured through pretest and posttest instruments. The pretest was used to assess students' initial abilities, while the posttest was used to measure improvements in students' abilities after learning, particularly in the domain of critical thinking. The trial was conducted in two stages: a limited trial in Grade V-B and a broad trial in Grades V-A and V-C. Prior to hypothesis testing, a normality test was conducted as a prerequisite to determine whether the data were normally distributed.

Table 3. Normality Test Results Limited Trial

Data	Statistic	df	Sig.
Pretest	0.963	34	0.258
Posttest	0.942	34	0.073

Based on the Shapiro-Wilk normality test results, the pretest and posttest data were found to be normally distributed, with significance values of 0.258 and 0.073 (Sig.

> 0.05), respectively. Therefore, analysis proceeded using the parametric paired sample t-test.

Table 4. Paired Sample T-Test Results Limited Trial

Pair	Mean Difference	Std. Dev.	t	df	Sig. (2-tailed)
Pretest- Posttest	-14.82	13.12	-6.52	33	0.000

The paired sample t-test yielded a significance value of 0.000 < 0.05, indicating that the use of the instructional media had a significant influence on the improvement of students' critical thinking skills. Following confirmation of the media's influence, an N-Gain test was conducted to determine the level of effectiveness of the improvement.

Table 5. N-Gain Results Limited Trial

Category	Number of Students	Percentage	Mean N-Gain
High	17	50%	0.85
Moderate	7	21%	0.50
Low	10	29%	0.04
Mean	34	100%	0.42

The limited trial results yielded a mean N-Gain of 0.42, classified in the moderate category. Of the students, 50% were in the high category, 21% in the moderate category, and 29% in the low category. This indicates that the use of the instructional media was moderately effective in improving students' critical thinking skills.

To further substantiate the findings, the broad trial was conducted. The broad trial aimed to examine the consistency of the interactive media's effectiveness in improving students' critical thinking skills with a larger subject sample, and to verify that the developed instructional media demonstrates a stable level of effectiveness that can be more widely applied.

Table 6. Normality Test Results Broad Trial

Data	Statistic	df	Sig.
Pretest	0.972	67	0.112
Posttest	0.957	67	0.058

Following the broad trial, the Shapiro-Wilk normality test confirmed that both the pretest and posttest data were normally distributed, with significance values of 0.112 and 0.058 (Sig. > 0.05), respectively. Accordingly, the parametric paired sample t-test was applied.

Table 7. Paired Sample T-Test Results Broad Trial

Pair	Mean Difference	Std. Dev.	t	df	Sig. (2-tailed)
Pretest- Posttest	-22.07	13.95	-13.31	66	0.000

The paired sample t-test again yielded a significance value of $0.000 < 0.05$, confirming that the use of the instructional media had a significant influence on the improvement of students' critical thinking skills. An N-Gain test was subsequently conducted to determine the effectiveness of the improvement.

Table 8. N-Gain Results Broad Trial

Category	Number of Students	Percentage	Mean N-Gain
High	35	52%	0.85
Moderate	22	33%	0.52
Low	10	15%	0.15
Mean	67	100%	0.63

The N-Gain calculation for the broad trial yielded a mean of 0.63, classified in the moderate category. Of the students, 52% were in the high category, 33% in the moderate category, and 15% in the low category. This indicates that the use of the instructional media was moderately effective in improving students' critical thinking skills.

Constraints in Using the Interactive Media

In addition to measuring improvements in students' critical thinking skills, this study also examined student responses toward the use of the instructional media. The analysis showed that students responded positively to the media used during the learning process. Furthermore, their responses also provided insights into the constraints encountered during the media's use.

Table 9. Student Response Questionnaire Results

Trial Stage	Aspect	Percentage	Criteria
Limited Trial	Attractiveness of media	82.25%	Excellent
	Ease of use	79.41%	Excellent
	Content comprehension	76.10%	Excellent
	Critical thinking	78.68%	Excellent
	Learning motivation	83.09%	Excellent
Broad Trial	Attractiveness of media	85.07%	Excellent
	Ease of use	79.85%	Excellent
	Content comprehension	79.48%	Excellent
	Critical thinking	79.10%	Excellent
	Learning motivation	84.14%	Excellent

Based on the student response questionnaire results, all aspects of the instructional media evaluation were rated in the "excellent" category. In the limited trial, the attractiveness of the media received a percentage of 82.25%, ease of use

79.41%, content comprehension 76.10%, critical thinking skills 78.68%, and learning motivation 83.09%. In the broad trial, improvements were noted in several aspects: attractiveness of the media rose to 85.07%, ease of use to 79.85%, content comprehension to 79.48%, critical thinking skills to 79.10%, and learning motivation to 84.14%. These results indicate that the developed instructional media received excellent responses from students in both the limited and broad trials, and can therefore be considered feasible and effective for use in the learning process. However, the primary constraint identified was that some students were not yet accustomed to using interactive media and had limited proficiency in operating devices, making them hesitant and lacking in confidence.

Discussion

This discussion section presents an analysis of the research findings obtained, with reference to the research questions established. The discussion is organized systematically to cover the interactive media development process, the feasibility of the developed media, the influence and effectiveness of its use on students' critical thinking skills, and the constraints encountered during the learning process.

Interactive Media Development Process

The interactive media development process in this study was carried out systematically following the ADDIE model stages: Analysis, Design, Development, Implementation, and Evaluation. In the analysis stage, learning needs for IPAS were identified through interviews with the Grade V classroom teacher, which revealed that the learning process was still dominated by lecture methods and video use, without interactive media to support active student participation. This situation resulted in students' limited ability to comprehend material in depth, analyze problems, and draw logical conclusions. Kustati (2026) found that instruction dominated by lecture methods tends to make students less active, resulting in suboptimal participation and engagement in the learning process. Based on these findings, the design stage focused on developing an initial draft of the interactive media, beginning with the creation of a storyboard, the formulation of learning outcomes and objectives, and the development of materials integrated with the SDGs 7 context. The accurate placement of learning outcomes and objectives plays a role in directing the learning process systematically so that expected results can be achieved effectively (Lestari et al., 2025).

The media design was subsequently realized using the Canva application, leveraging its available visual and interactive features. The use of Canva in developing interactive media facilitates the design of visually engaging learning presentations by integrating visual elements, text, and animations, as well as interactive navigation features that allow students to access materials flexibly, thereby supporting a more communicative and interactive presentation of content (Afriyeni & Melani, 2024). The content and material explanations within the interactive media were supplemented with contextually relevant images related to real-life situations, and the media interface

was designed to be highly attractive in accordance with the characteristics of elementary school students. On the opening page, the media displays the learning title and a "Start" button as the entry point for initiating learning activities. Subsequently, a brief introduction to SDGs 7 is presented, providing students with initial context regarding the issue of clean energy and the importance of sustainability. Students are then directed to the main page, comprising a "Your Adventure" menu containing five STEM-based learning steps, from the problem-solving stage to the presentation stage. This menu allows students to navigate the learning sequence as designed. Within each selected learning step, materials are presented across four sessions (Session 1 through Session 4). Each session maintains a consistent learning structure comprising content presentation, stimulus questions, a quiz, and group discussion activities. Through this design, the media not only functions as a content delivery tool but also as a means of promoting students' active engagement in the learning process. Students are guided to observe problems, engage in critical thinking through stimulus questions, collaborate in discussions, and communicate results through presentation activities. Previous research has indicated that students demonstrate greater interest and enthusiasm toward interactive media that features engaging visuals such as attractive images and colors, and that connects material to everyday events (Fitriani, 2025). This is supported by cognitivist theory, which posits that elementary school students at the concrete operational stage (ages 7–11) are beginning to think logically about concrete events (Amini et al., 2024). Thus, this media development process is expected to produce a product capable of enhancing students' critical thinking skills.

In the development stage, the interactive media was built into a product ready for use in the learning process. The completed interactive media was then validated by experts to assess the product's feasibility in terms of content, visual presentation, and usability. This validation was conducted by a media expert and a content expert. The validation results indicated that the developed media was categorized as feasible for use in the learning process. In the implementation stage, the revised media was trialed to determine its influence and effectiveness. Measurements were taken using pretest and posttest instruments to compare students' abilities before and after learning. The trial was conducted in two stages: a limited trial and a broad trial. The limited trial aimed to determine students' initial responses to the interactive media and to identify any shortcomings. The broad trial was conducted to examine the consistency of the media's effectiveness with a larger number of subjects and to verify that the developed instructional media demonstrates a stable level of effectiveness suitable for broader application. In addition to testing media use, this stage also aimed to assess the influence and effectiveness of the media in improving students' critical thinking skills, measured through a comparison of pretest and posttest results using statistical tests, including normality tests, t-tests, and N-Gain calculations. These analyses provided an overview of the improvement in students' learning outcomes following the use of the interactive media. Student responses were also collected through questionnaires to assess media attractiveness, ease of use, content comprehension, critical thinking skills,

and learning motivation, all of which formed an important basis for determining the media's alignment with students' needs and characteristics.

The final stage of the ADDIE model was Evaluation, during which all assessment results were processed and conclusions drawn regarding the quality of the developed instructional media. Based on the validation results from the media and content experts, as well as the student trial results from both the limited and broad trials, the developed instructional media was determined to be feasible for use in the learning process. Additionally, the analysis results indicated that the use of the interactive media was effective in improving students' critical thinking skills and received positive responses from students, despite some constraints encountered during its use. This is consistent with Syafilullah and Lastuti (2025), who demonstrated that the use of interactive media is highly effective in improving learners' critical thinking skills. Through this evaluation stage, the developed interactive media is expected to be further refined to meet practical needs in classroom learning.

Feasibility of the Interactive Media

Based on the research findings described above, the SDGs 7-based interactive learning medium supported by STEM learning has met the feasibility criteria and is effective in improving the critical thinking skills of elementary school students. The feasibility assessment was conducted by two validators with competence in the respective domains of media and content development. This is consistent with the view of Azkiya et al. (2022), who stated that expert assessment is necessary to ensure the developed product can meet the expected learning objectives. The validation results for the developed interactive media were categorized as "highly feasible" by both the media and content validators. High-quality instructional media must meet the criteria of content feasibility, visual presentation, and ease of use to optimally support the learning process (Miftah, 2023). Consistent with Latifah and Agestiana (2020), when the feasibility assessment yields a "highly feasible" category, the developed interactive media can be used by learners as a supporting tool in the learning process. This indicates that the media designed was appropriate for learning needs in terms of visual appearance, content, and alignment with learner characteristics (Kurniawan, 2017). The revision implemented based on the media expert's suggestions involved adjusting the font size within the interactive media, which contributed to improving the media's quality in terms of usability and comprehensibility for students (Kamila et al., 2024).

Influence and Effectiveness of the Interactive Media

The influence and effectiveness of the interactive media in this study were measured using pretest and posttest instruments. The pretest was used to determine students' baseline abilities prior to learning with the interactive media, while the posttest was used to measure their abilities after the learning process, particularly in the domain of critical thinking skills. The influence and effectiveness of the product

refer to the extent to which the interactive media was capable of improving learners' academic outcomes during the learning process (Aulia & Aufa, 2024).

The trial results demonstrated that the use of the interactive media had a significant influence on the improvement of students' critical thinking skills, as evidenced by the paired sample t-test results yielding a significance value below 0.05. These findings indicate a significant difference between the pretest and posttest results following the use of the instructional media. Accordingly, the developed interactive media was able to produce a positive effect on students' learning outcomes, particularly in the domain of critical thinking. Critical thinking involves processes of analysis, evaluation, and decision-making that can be cultivated through active and meaningful learning (Kusuma et al., 2024; Manurung et al., 2023). Interactive media can attract students' attention through its visual presentation, animations, and direct interaction during media use, making students more actively engaged than in conventional, passive learning. This increased active involvement enhances students' focus, motivation, and comprehension of the material. This is supported by Mubarrok et al. (2025), who argued that interactive instructional media encourages active student participation through engaging and responsive content presentation, thereby enhancing student engagement in the learning process. According to cognitive learning theory (cited in Basyir et al., 2022), the learning process is more important than the final outcome, as learning involves complex cognitive processes rather than a simple stimulus-response relationship. In this context, the use of interactive instructional media supports students' cognitive processes through visualization, exploration, and direct interaction, making learning more meaningful.

The effectiveness of the interactive media in improving students' critical thinking skills is supported by the N-Gain test results, which showed moderate improvement, with a proportion of students reaching the high category. This confirms that the interactive media was sufficiently effective in improving students' learning outcomes. The improvement in students' critical thinking skills is inseparable from the STEM learning mechanism applied within the interactive media. The integration of STEM learning directly engaged students in a problem-solving process that incorporated an understanding of the concept of energy in everyday life, the utilization of technology in the use of energy sources, the design and creation of projects as solutions, and the calculation of material and energy use. Through this process, students not only acquired content knowledge but were also trained to analyze, evaluate, and make decisions logically. Previous research supports this finding, indicating that STEM learning emphasizes a problem-based and real-world experiential learning process, whereby students are not merely receivers of information but are engaged in exploration, analysis, and evaluation (Topsakal et al., 2022). This is consistent with Kelley and Knowles (2016), who stated that STEM learning integrates various disciplines to solve real-world problems, and is further supported by Thibaut et al. (2018), who demonstrated that STEM promotes active student engagement through exploratory and analytical processes.

The integration of STEM learning within the interactive media enabled students to engage with contextual problems related to the clean energy issue in SDGs 7, making the material more relevant and accessible. This contextual learning approach encouraged students to connect concepts with real-world situations and to develop critical thinking skills through the processes of problem identification, analysis, and logical solution formulation. This is consistent with previous research indicating that learning that connects science concepts with real environmental problems can enhance students' focus on mastering STEM learning concepts as well as developing higher-order thinking skills and environmental awareness (Vilmala et al., 2025; Susilawati et al., 2025). This is further supported by Emilidha and Waluya (2024), who found that STEM-based learning can integrate knowledge and skills to solve real-world problems, thereby enhancing students' critical thinking skills.

Constraints in Using the Interactive Media

The developed interactive media product received excellent student responses, as evidenced by the questionnaires completed during the limited and broad trials. These excellent responses covered all assessed aspects, including attractiveness, ease of use, content comprehension, critical thinking skills, and learning motivation. This demonstrates that the interactive media was effective in enhancing student engagement in the learning process, making instruction more active and less monotonous. Attractive and interactive media also helps students to comprehend material more deeply and encourages them to think and participate more actively (Ali et al., 2025). This is further explained through behaviorist theory, which emphasizes that behavioral changes in learning result from the interaction between stimulus and response (Nahar, 2016; Damayanti, A., & Kelana, J. B., 2025).

Nevertheless, several constraints were identified during implementation. Students' prior understanding of SDGs 7 was relatively low, as the majority had limited exposure to this concept. Students tended to comprehend energy-related material only at a general level, without connecting it to aspects of sustainability or to the broader objectives of efficient and responsible energy use (Fitriani et al., 2025). Additionally, some students were not yet accustomed to using interactive media and had limited device-operating proficiency. During learning sessions utilizing interactive media, students tended to feel confused and hesitant when not yet sufficiently guided, out of fear of making errors in operation. Students were accustomed to watching instructional videos presented by their teachers without directly interacting with devices. Accordingly, the effective use of technology in learning requires adequate readiness in terms of both infrastructure and user competence (Sufriadi et al., 2022; Melisa, 2024). Teacher mentoring also needs to be maximized to ensure optimal utilization of the interactive media (Poerwanti & Mahfud, 2018). Nonetheless, these constraints did not diminish the overall effectiveness of the media. They serve as points for evaluation and improvement of the interactive media in the future. Proposed measures include providing more detailed content explanations prior to media use, as well as

familiarizing students with technology devices during learning through more intensive teacher guidance. With these evaluations, the SDGs 7-based interactive media supported by STEM learning is expected to be further developed and optimized for broader application in the learning process.

CONCLUSION

Based on the research findings and discussion, this study concludes that the SDG 7-based interactive media integrated with STEM learning was successfully developed to improve elementary school students' critical thinking skills. The development process followed the R&D method using the ADDIE model, which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation. The developed media incorporated STEM learning syntax into interactive learning content grounded in SDG 7, particularly the topic of energy and its utilization. Through this integration, the media was designed not only to support students' conceptual understanding of clean and affordable energy but also to encourage problem analysis, logical reasoning, and solution formulation. The feasibility results showed that the developed interactive media was highly feasible for use in elementary school learning. This was indicated by the validation scores from the media expert and content expert, which reached 95% and 82%, respectively. These results suggest that the media met the expected standards in terms of visual design, content relevance, usability, and alignment with students' learning characteristics. Furthermore, the implementation results showed that the use of the interactive media had a significant positive effect on students' critical thinking skills, as supported by the paired sample t-test results with a significance value of < 0.05 . The N-Gain results, which were categorized as moderate, further indicated that the media contributed to improving students' critical thinking skills, although the effectiveness was observed within a one-group design without a control group. In addition, students gave excellent responses to the interactive media, particularly in terms of attractiveness, ease of use, content comprehension, critical thinking support, and learning motivation. These findings indicate that the media encouraged student engagement and active participation during the learning process. However, this study has several limitations, including its implementation in only one school, the absence of a control group, the focus on SDG 7 content, and limited research time. Other challenges were also identified, such as students' limited prior knowledge of SDG 7 concepts and their unfamiliarity with operating technology-based learning media. Therefore, future studies are recommended to involve broader research settings, use comparative or experimental designs, and develop interactive media for other SDG-related topics to strengthen the generalizability and effectiveness of the findings.

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