Revision_Serli Ahzari_Akmam_Jurnal Pendidikan Fisika.docx

by Brice Crowell

Submission date: 04-May-2025 01:02PM (UTC+0300)
Submission ID: 2665688351
File name: Revision_Serli_Ahzari_Akmam_Jurnal_Pendidikan_Fisika.docx (257.04K)
Word count: 4713
Character count: 31419

JPF | Volume XX | Number X | Year | Page X-X

p - ISSN: 2302-8939
e - ISSN: 2527-4015

Jurnal Pendidikan Fisika

https://journal.unismuh.ac.id/index.php/jpf

DOI: 10.26618/jpf/xxxx

Analysis of Students' Critical Thinking Skills to Develop Physics Interactive Multimedia Based on a Generative Learning Model with Cognitive Conflict Strategy

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Received: Month XX,20XX; Accepted: Month XX, 20XX; Published: Month XX, 20XX

Abstract *– The rapid technological advancement in the 21st century has transformed educational approaches, particularly in physics education, where students often struggle with abstract concepts. This study aims to analyze students' critical thinking skills to develop physics interactive multimedia based on a generative learning model with cognitive conflict strategy. The researchers conducted the research in three public high schools in Lima Puluh Kota Regency using a descriptive survey method with a quantitative approach involving 125 eleventh-grade students. Data collection employed five validated instruments: teacher response questionnaires on learning models and critical thinking, multimedia needs analysis questionnaires, student attitude questionnaires toward physics learning, learning style questionnaires, and critical thinking skills tests. The research findings reveal three key insights: First, current physics learning primarily utilizes simple media like PowerPoint presentations, videos, and real objects, indicating a significant need for interactive multimedia development. Second, students exhibit diverse learning styles, with visual learning predominant (53.06%), suggesting the importance of developing multimedia accommodating various learning preferences. Third, while students maintain moderately positive attitudes toward physics learning (65.69%), their critical thinking skills remain critically low (27.80%), revealing a substantial attention gap. These findings suggest the need to develop physics interactive multimedia based on a generative learning model with a cognitive conflict strategy that maximizes visual and interactive elements. Such development addresses students' low critical thinking skills by creating cognitive conflicts and encouraging deeper thinking while accommodating their diverse learning styles, particularly the prevalent visual learning preference in physics education.*

Keywords: *Critical Thinking; Interactive Multimedia; Generative Learning; Cognitive Conflict; Physics*

I. INTRODUCTION

Technology integration in education has become imperative in the 21st century, particularly in physics education, where abstract concepts and complex mathematical representations pose unique pedagogical challenges. This technological integration is essential for preparing students to meet future

p - ISSN: 2302-8939
e - ISSN: 2527-4015

challenges in an increasingly digital world (Elihami & Saharuddin, 2018). The importance of this research lies in addressing the critical gap between technological advancement and its practical implementation in physics education, where students' critical thinking development remains a primary concern for educators and policymakers alike.

Physics education faces distinctive challenges that other disciplines may not encounter to the same degree. Students often perceive physics as highly abstract, mathematically demanding, and disconnected from everyday experiences, resulting in decreased motivation and difficulty understanding foundational concepts (Dewi et al., 2017; Maunino et al., 2023). The multidimensional nature of physics—requiring simultaneous mastery of conceptual understanding, mathematical formalism, and experimental reasoning—creates significant cognitive demands on students. Conventional teaching approaches frequently emphasize theoretical content over practical applications, neglecting the development of critical problem-solving abilities essential for physics mastery (Azizah et al., 2017). Additionally, students struggle to connect theoretical concepts with real-world applications, making learning experiences less meaningful and more challenging to internalize (Wulandari et al., 2023).

Observations at several high schools in Lima Puluh Kota Regency reveal specific problems in physics education. Teachers predominantly use conventional teaching methods and simple media such as PowerPoint presentations and occasional videos, which fail to address students' diverse learning styles. These traditional approaches do not adequately visualize abstract physics concepts or engage students in active learning experiences. A preliminary assessment indicates that students' critical thinking skills remain underdeveloped, with most students demonstrating difficulties in independently analyzing, evaluating, and constructing physics knowledge. This situation necessitates innovative approaches to enhance conceptual understanding and critical thinking development in physics.

Recent research has explored various solutions to address these challenges. Interactive multimedia has become a powerful tool for enhancing student engagement and conceptual understanding in physics education. Studies by Nurhalimah and Rizal (2024) and Tanti et al. (2024) demonstrate that well-designed multimedia can significantly improve student engagement, conceptual understanding, and information retention in physics learning. Learning multimedia's visual and interactive characteristics makes abstract concepts more concrete and manageable for students to comprehend. Meanwhile, pedagogical approaches like generative learning models and cognitive conflict strategies have shown promise in developing students' higher-order thinking skills. Research by Agustin & Akmam (2024) and Akmam et al. (2023, 2024) confirm the effectiveness of these approaches in different educational contexts, particularly in science learning, where they actively engage students in knowledge construction rather than passive information reception.

Despite these advancements, significant research gaps remain in understanding how to effectively integrate generative learning models and cognitive conflict strategies within interactive multimedia environments specifically for physics education. Previous studies by Abdul et al. (2016) have

p - ISSN: 2302-8939
e - ISSN: 2527-4015

demonstrated generally positive outcomes when combining multimedia learning with active pedagogical approaches, showing significantly better learning outcomes compared to conventional methods. However, these studies have not adequately investigated how cognitive conflict strategies might be systematically incorporated into interactive multimedia designs to address specific misconceptions in physics. Moreover, existing research has not sufficiently examined how this integration might specifically enhance critical thinking skills development in physics education contexts. The unique challenges of representing complex physics phenomena in interactive multimedia formats—balancing scientific accuracy with user-friendliness and maintaining high student engagement (Buelow et al., 2019; Unal & Cakir, 2021)—further complicate this integration and require specialized research attention.

This study aims to analyze students' critical thinking skills as a foundation for developing physics interactive multimedia based on a generative learning model with cognitive conflict strategy. The research specifically addresses the question: What is the current level of critical thinking skills among high school students in Lima Puluh Kota Regency, and how can this understanding inform the development of practical physics interactive multimedia that integrates generative learning models and cognitive conflict strategies? The findings from this research are expected to contribute significantly to a broader understanding of technology utilization in supporting students' critical thinking skills development. Furthermore, this research is anticipated to bridge existing gaps in current educational practices and literature, serving as a reference for educators and multimedia learning developers in designing and implementing effective technology-based learning in physics education.

II. METHODS

Research Methodology

This study employs a descriptive survey method with a quantitative approach to systematically analyze students' critical thinking skills in physics learning. The research examines multiple dimensions, including learning styles, student attitudes, interactive multimedia needs, and learning model implementation as a foundation for developing physics interactive multimedia based on a generative learning model with cognitive conflict strategy. The research procedure followed three main phases: preparation, implementation, and final analysis, as illustrated in Figure 1.

Figure 1. Research Procedure

During the preparation phase, preliminary observations were conducted at the selected schools to identify existing teaching practices and student learning environments. The researchers conducted a comprehensive literature review on critical thinking skills, generative learning models, cognitive conflict strategies, and interactive multimedia development in physics education. Research instruments

JPF | Volume XX | Number X | Year | Page X-X
p - ISSN: 2302-8939
e - ISSN: 2527-4015

were then systematically developed and validated by three physics education experts before obtaining necessary research permits from the regional education authorities of Lima Puluh Kota Regency.

Research Location and Subjects

In the implementation phase, data was collected over approximately four weeks across three public high schools in Lima Puluh Kota Regency. These schools were selected based on their 2024 accreditation levels (high, medium, and low) to ensure representation of diverse educational environments. The research subjects included 125 eleventh-grade students (Phase F) enrolled in physics classes distributed across the three schools, as presented in Table 1.

Table 1. Distribution of Research Subjects

School	Accreditation Level	Number of Students
SHS A	High	49
SHS B	Medium	48
SHS C	Low	28
Total		125

Data Collection Techniques

Data collection was performed using five validated instruments. First, a questionnaire on physics teachers' responses toward the Generative Learning Model with Cognitive Conflict Strategy and Critical Thinking Skills in Grade XI Senior High School Physics Learning, consisting of 2 main components: a section on the Generative Learning Model with Cognitive Conflict Strategy in Physics Learning with 6 statement points and a section on Critical Thinking Skills in Physics Learning with 5 statement points. This instrument used a 5-point Likert scale.

Second, a questionnaire analyzing the need for interactive multimedia in Grade XI Phase F Senior High School Physics Learning provided teachers with 18 statements consisting of multiple-choice answers and short responses. Third, a questionnaire analyzing students' attitudes toward physics learning for Grade XI Phase F Senior High School students, adopted from CLASS (Colorado Learning Attitude about Science Survey), using a 5-point Likert scale: 1. Strongly Disagree, 2. Disagree, 3. Neutral, 4. Agree, 5. Strongly Agree. This questionnaire contained 30 statements with one distractor statement. Fourth, a learning style questionnaire for Grade XI Phase F Senior High School students (adopted from the Student Learning Style Questionnaire by Akhmad Sugianto, S.Pd., M.Pd), containing 14 statements with three answer choices for each statement. Fifth, a critical thinking skills test sheet for Grade XI Phase F Senior High School students, consisting of 5 contextual physics phenomenon-based questions in narrative form.

Data Analysis Technique

The final phase involved comprehensive data analysis. The collected data was analyzed descriptively to obtain a comprehensive statistical overview of students' critical thinking skills. For

p - ISSN: 2302-8939
e - ISSN: 2527-4015

critical thinking skills analysis, initial scores were converted to a 100-point scale using the following formula by Purwanto (2008):

$$S = \frac{R}{N} x\ 100\%$$

Where:

S = Percentage of critical thinking skills

R = Total score obtained by the student

N = Maximum test score

The calculated percentages were then categorized according to the critical thinking skills assessment criteria, as shown in Table 2.

Table 2. Critical Thinking Skills Assessment Criteria

Interval	Criteria
86% - 100%	Very high
76% - 86%	High
60% - 75%	Middle
55% - 59%	Low
≤54%	Very Low

(Purwanto, 2008)

III. RESULTS AND DISCUSSION

The results of the study are described in the following aspects:

Analysis of Interactive Physics Multimedia Needs

Based on questionnaire analysis administered to 3 Physics teachers teaching 11th Grade Phase F in 3 different Lima Puluh Kota Regency high schools, it was found that teachers primarily use simple media such as PowerPoint presentations, learning videos, audio, and real objects. Using such media in physics learning tends not to meet students' diverse learning styles and does not optimally support the development of critical thinking skills. PowerPoint presentations are often static and function only as one-way tools, making students passive listeners without active interaction. Although learning videos can be more engaging, their content is linear and offers limited opportunities for students to interact or explore the material independently. Audio usage is restricted because it relies solely on hearing, making it less suitable for students with visual or kinesthetic learning styles. Real objects, though more concrete, are often limited in accessibility and challenging to manage effectively in the classroom.

Field observations revealed that teachers have not widely adopted interactive multimedia due to time constraints for learning and developing new media, compounded by the lack of technological facilities in schools and teachers' limited technical skills. Without adequate training and facilities, teachers are more likely to use simple learning media they have already mastered. The lack of engagement inhibits interactivity in learning, which crucially promotes students' critical thinking skills (Ennis, 2011). Therefore, developing interactive multimedia, such as virtual labs, simulations, and interactive tutorials, based on generative learning models and cognitive conflict strategies is urgently needed to facilitate student engagement and support the development of student's critical thinking skills.

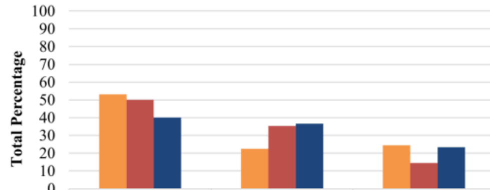
Analysis of Learning Model Implementation

Regarding implementing learning models, teachers frequently use discovery, problem-based, and project-based learning. While these models effectively promote independent learning, they often lack depth in stimulating students' critical thinking skills. Critical thinking skills are crucial in Physics learning, which requires students to analyze, evaluate, and solve problems with a more structured and in-depth approach (Fisher, 2015). The weakness of existing learning models is the lack of cognitive challenges that can prompt students to think critically. Therefore, developing interactive multimedia based on generative learning models with cognitive conflict strategies is essential, as this strategy can create cognitive conflicts that encourage students to think more deeply, explore new ideas, and discover innovative solutions (Mayer, 2020).

Interactive multimedia enriches students' learning experiences by providing an active and participatory learning environment crucial for enhancing critical thinking skills. Specifically, interactive multimedia fosters critical thinking through several mechanisms: (1) scenario-based simulations that allow students to analyze complex situations and make informed decisions, (2) interactive data visualization features that Help students identify patterns and cause-effect relationships, (3) real-time feedback systems that encourage students to evaluate their solutions and identify conceptual misconceptions, and (4) multimedia-based collaborative tasks that require students to communicate their reasoning and respond to alternative perspectives (Ahzari & Asrizal, 2023; Asrizal et al., 2025; Hamdani et al., 2022; Rogti, 2024). The ability of interactive multimedia to integrate elements of problem-based learning and discovery learning also facilitates the application of Bloom's higher-order cognitive taxonomy—analysis, evaluation, and creation—at the core of critical thinking. Given the limitations of teachers' facilities and technical abilities, interactive multimedia can be an important tool to Help them adopt this learning model more effectively.

Student Characteristics Analysis

Student characteristics analysis is necessary to understand students' traits as a basis for considerations in developing learning models. The student characteristics examined include their learning styles and attitudes towards Physics learning. The respondents were 125 11th-grade Phase F students from 3 different Lima Puluh Kota Regency Senior High Schools (SHS). The analysis of students' learning styles is presented in Figure 2 below.

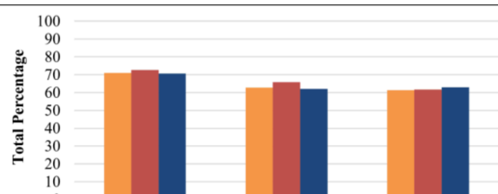


	Visual	Auditory	Kinesthetic
SHS A	53.06	22.45	24.49
SHS B	50.00	35.42	14.58
SHS C	40.00	36.67	23.33

Learning Style

Figure 2. Students' Learning Style

The analysis reveals that students possess diverse learning styles, as evidenced by the distribution across three schools. This diversity indicates the necessity of learning models and educational media that can accommodate various learning styles to ensure the effectiveness of the teaching and learning process. With most students exhibiting a visual learning style, reaching 53.06% at SHS A, followed by auditory and kinesthetic styles, it is crucial to develop interactive multimedia that is visually engaging and integrates auditory and kinesthetic elements. This approach will Help create a more inclusive and dynamic learning experience, enhancing student engagement in the learning process and developing the essential critical thinking skills crucial in Physics learning. Furthermore, regarding students' attitudes towards Physics learning, based on the questionnaire distributed to students, their attitude towards Physics learning is quite positive, with 65.69% showing a favorable disposition. The graph analyzing students' attitudes across different indicators is presented in Figure 3.



	Learning Attitude	Material Attitude	Learning Effort
SHS A	71.10	62.71	61.31
SHS B	72.61	65.90	61.76
SHS C	70.67	62.11	63.00

Indicators of Student Attitudes

Figure 3. Indicators of Student Attitudes

Based on the questionnaire distributed to 11th Grade Phase F students across three schools in Lima Puluh Kota Regency, with 125 respondents, the table displays student attitude indicators in three senior high schools (SHS A, SHS B, and SHS C) in three categories: learning attitude, material attitude, and learning effort. The average student learning attitude reaches 71.46%, with SHS B recording the highest percentage (72.61%), indicating a reasonably positive attitude towards the learning process.

However, in the material attitude category, the average is only 63.57%, signaling room for improvement in student engagement with the subject matter, whereas SHS B again holds the highest percentage (65.90%). Regarding learning effort, students average only 62.02%, with SHS C recording the highest percentage (63.00%), demonstrating challenges in learning motivation. Overall, while students' learning attitudes are relatively positive, there is a clear need to enhance their attitudes towards learning materials and their learning efforts.

These findings underscore the importance of developing more interactive and engaging learning strategies, such as interactive multimedia based on generative learning models, to support and improve student engagement and positive attitudes toward learning. Positive attitudes toward physics learning can increase student motivation and effort in understanding the concepts taught (Husein et al., 2017). Analyzing students' attitudes towards Physics learning is crucial to understanding their readiness to engage in interactive multimedia-based learning.

Critical Thinking Skills Analysis

The student's critical thinking skills were analyzed from test question sheets given to 11th-grade Phase F students in three different state high schools in Lima Puluh Kota Regency. The aim was to measure students' critical thinking skills. Five indicators assessed critical thinking skills: interpretation, analysis, evaluation, inference, and explanation (Facione, 2011). Based on the test questions, students' critical thinking skills remain low, with approximately 27.80% proficiency. The graph analyzing critical thinking skills by indicator is presented in Figure 4.

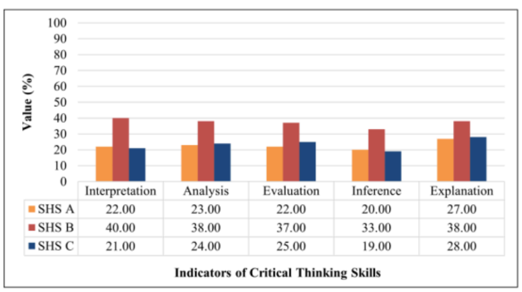


Figure 4. Critical Thinking Skills Analysis Results Per Indicator

Based on the questionnaire distributed to 11th Grade Phase F students across three schools in Lima Puluh Kota Regency, with a total of 125 respondents, the critical thinking skills analysis revealed the following: First, the average scores for interpretation, analysis, and evaluation indicators are 27.67%; 28.33; and 28.00 which falls into the low category. Second, the average inference indicator is 24.00%, also categorized as low. Third, the explanation indicator averages 31.00%, again in the low category. The explanation indicator is the highest among the five indicators yet remains in the low category.

Students' critical thinking skills must be significantly improved, as they should ideally be in the very high category. Therefore, there is a crucial need for interactive physics multimedia based on generative learning models with cognitive conflict strategies that can effectively enhance students' critical thinking skills. The analysis underscores the importance of developing innovative educational approaches that systematically improve students' ability to interpret, analyze, evaluate, draw inferences, and explain complex scientific concepts. The consistently low performance across critical thinking indicators suggests that teaching methods must be improved to foster the deep, analytical thinking required in physics education.

These findings align with research by Haris et al. (2024), which reveals that 75.50% of high school students in Makassar City demonstrate low critical thinking skills in physics problem-solving. The limited critical thinking abilities observed in our study (27.80%) are comparable to findings from Prabayanti et al. (2024), who found that 60% of students at SMAN 5 Sidrap fell into the low category for critical thinking skills when studying Newton's Laws. Further support comes from Gunawan et al. (2024), whose research with prospective science teachers identified persistent difficulties across multiple critical thinking indicators, including inference, advanced clarification, and strategy formulation. The research evidence confirms a consistent pattern of underdeveloped critical thinking skills in physics education across Indonesia's educational levels and context.

The predominance of visual learning styles among students (approximately 50% across schools studied) highlights a significant reliance on visual aids in learning, though specific percentages vary in the literature. This finding aligns with research by Tanti et al. (2024), which demonstrates that interactive visual elements in learning resources significantly enhance students' conceptual understanding of physics. Students with visual learning tendencies benefit substantially from instructional strategies incorporating visual representations—diagrams, animations, and multimedia resources—that make abstract physics concepts more concrete and accessible (Bobek & Tversky, 2016; Bouchée et al., 2022; Nasution et al., 2025). Laurenty et al. (2024) similarly found that interactive and visually engaging materials improve conceptual understanding, suggesting educators should integrate these elements into their instructional approaches. Research indicates that tailored multimedia materials in physics lessons have boosted student engagement dramatically (from 45% to 85%) and significantly raised post-test scores, demonstrating better comprehension and retention of concepts (Nasution et al., 2025).

Furthermore, our comparative analysis revealed that explanation skills (31.00%) were relatively stronger than inference skills (24.00%), consistent with findings from Agustin & Akmam (2024) and Raisal et al. (2023), who noted that students typically develop explanation abilities before mastering more complex inferential reasoning in physics education. While visual learning preferences are important, conceptual understanding in physics is also influenced by cognitive styles and student interest (Devy et al., 2022), with cooperative and interactive learning strategies further enhancing comprehension when combined with visual elements, particularly for students with converger learning styles (Kade et al., 2019). This integrated pedagogical approach clarifies complex ideas and fosters deeper engagement and more robust learning outcomes in physics education.

The moderately positive attitudes toward physics learning (65.69%) but low scores in learning effort (62.02%) reflect a disconnect between students' theoretical appreciation of physics and their willingness to engage deeply with the subject. This observation is consistent with Husein et al. (2017), who found that positive attitudes alone do not translate to improved learning outcomes without engaging learning experiences. These findings suggest that interactive multimedia must present content effectively and cultivate greater student engagement and motivation.

The implications of these findings are significant for physics education. First, they highlight the urgent need for learning resources that specifically target critical thinking development rather than merely focusing on content delivery. Second, they demonstrate that adequate learning resources must be designed considering students' learning preferences, particularly visual learning modalities. Third, they suggest that generative learning models with cognitive conflict strategies offer promising approaches to developing the specific critical thinking skills lacking in this study.

Developing interactive multimedia based on these findings could significantly address the persistent challenges in physics education. By creating resources that engage students visually, challenge misconceptions through cognitive conflict, and provide opportunities for active knowledge construction, educators may more effectively develop the critical thinking capabilities essential for success in physics and beyond.

IV. CONCLUSION AND SUGGESTION

This study analyzed students' critical thinking skills to develop physics interactive multimedia using a generative learning model with cognitive conflict strategy. The research findings lead to several important conclusions. First, physics learning requires significant interactive multimedia development, as teachers use only simple tools like PowerPoint presentations, videos, and real objects that fail to engage students in active learning adequately. Second, students exhibit diverse learning styles, with visual learning emerging as the predominant style (53.06%), highlighting the need to develop multimedia accommodating various learning preferences. Third, while students maintain moderately positive attitudes toward physics learning (65.69%), their critical thinking skills remain critically low (27.80%), particularly in inference skills (24.00%) compared to explanation skills (31.00%), revealing a substantial gap requiring attention. The findings suggest the need for further research to develop physics interactive multimedia based on a generative learning model with a cognitive conflict strategy that maximizes visual and interactive elements, considering the prevalence of visual learning styles among students. The multimedia development should effectively integrate the generative learning model and cognitive conflict strategy to enhance students' critical thinking skills. This development addresses students' low critical thinking skills by creating cognitive conflicts and encouraging deeper thinking while accommodating their diverse learning styles, particularly the prevalent visual learning preference in physics education.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the financial support provided by the Directorate of Research, Technology, and Community Service, the Directorate General of Higher Education, Research and Technology, and the Ministry of Education, Culture, Research, and Technology according to research implementation contract number 069/E5/PG.02.00.PL/2024, and Universitas Negeri Padang (PPS-PTM 2024) number 2638/UN35.15/LT/2024.

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