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Harnessing Educational Media to Cultivate Critical Thinking in STEM Learning Environments

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Abstract:
This study aims to analyze the role of educational media in improving students' critical thinking skills in a STEM learning environment. Using a qualitative case study approach, this study examines how educational technology can be integrated into STEM teaching to facilitate analytical thinking and problem solving. The subjects of the study included the principal, vice curriculum, teachers and students, at SMAN 1 Paiton Probolinggo. Data collection techniques included classroom observation, in-depth interviews, and documentation analysis. Data were analyzed through the process of data reduction, data presentation, and drawing conclusions. The results showed that high-tech educational media were able to create a more interactive and engaging learning environment, which encouraged students to think critically and solve problems in the STEM context independently. The implementation of interactive media was proven effective in improving students' understanding of STEM concepts, strengthening higher-order thinking skills, and motivating students to be more active in the learning process. On the other hand, teacher competence in using educational media optimally played a key role in achieving the expected learning outcomes. These findings contribute to the STEM education literature and offer new perspectives on how educational media can be utilized to prepare students for real-world challenges through the development of critical thinking skills.

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INTRODUCTION

The use of educational media in STEM learning is not only a tool, but also a means to instill ethical values and critical thinking skills(Marosi et al., 2024). Through this media, students are trained to analyze information, identify problems, and create responsible solutions(Yasifa et al., 2023). This is because educational media has great potential to present interactive and contextual learning situations, allowing students to develop crical thinking skills while still internalizing moral values(Ali et al., 2021). By presenting various case studies, simulations, and problem-solving scenarios, educational media can help students understand the ethical impact of their choices in solving problems(Victoria et al., 2024). One piece of evidence supporting the moral role

of educational media in developing critical thinking and ethical values in students in the STEM environment can be found in research by (Yang & Baldwin, 2020), which states that critical thinking involves deep analytical, evaluation, and reflective thinking skills, which are closely related to the development of moral responsibility(Ayanwale et al., 2024). Thus, the use of educational media in STEM learning not only improves students' technical abilities, but also plays an important role in shaping ethical values and critical thinking skills(Oktapiani & Hamdu, 2020). Wise media design can create an interactive and contextual learning environment, allowing students to understand the ethical impact of their decisions.

Studies on the use of educational media in STEM learning have a significant impact on the development of students' critical thinking skills and ethical values. According to (Park & Cho, 2022), critical thinking involves analysis and evaluation skills that are essential for the development of moral responsibility. This is reinforced by the study of (Damayanti et al., 2024), which found that media designed with a moral approach can help students make more responsible decisions. In addition, (Fakhrudin et al., 2023) emphasized the importance of interactive media that allows students to engage in problem-solving scenarios, so that they can understand the ethical consequences of the choices made. Research by (Muttaqiin, 2023) also showed that the use of simulations in STEM learning improves students' ability to think critically and understand moral values. Thus, the integration of educational media can effectively contribute to the development of students' character in the STEM field.

The novelty of using educational media in STEM learning lies in the integration of cutting-edge technologies, such as artificial intelligence (AI) and virtual reality (VR), to create immersive and personalized learning experiences. By leveraging AI, educational media can be tailored to students' individual needs, providing real-time feedback and helping them explore STEM concepts more interactively(Wahyudin & Permatasari, 2020). In addition, the use of VR allows students to experience complex real-world situations, such as scientific experiments or engineering challenges, without the risks inherent in a physical environment. This approach not only strengthens students' critical thinking skills but also instills a deeper ethical understanding of the impact of their decisions(Putri et al., 2021). Thus, this innovation not only increases student engagement but also prepares them to become responsible critical thinkers in the future.

This study confirms that the use of educational media in STEM learning aims to improve critical thinking skills and instill ethical values in students. The argument underlying this goal is that educational media, designed with an interactive and contextual approach, allows students to be actively involved in the learning process(Mili et al., 2023)(Munawwaroh, 2024). Through information analysis, problem identification, and solution development, students not only learn technical skills but also understand the ethical impact of the decisions they make(Poszler & Lange, 2024). This study shows that the integration of modern technologies, such as artificial intelligence and virtual reality, further strengthens the effectiveness of educational media in creating immersive learning experiences(Alkaeed et al., 2023). Thus, this study makes a significant contribution to the development of learning methods that not only focus on

academic aspects but also on the formation of student character in the STEM environment.

RESEARCH METHOD

This study aims to explore and analyze how the use of educational media can help develop critical thinking skills in a STEM learning environment. This study uses a qualitative approach with a case study method. The selection of a case study allows researchers to understand complex phenomena in a specific context, namely in the STEM education environment at SMAN 1 Paiton Probolinggo. Through this approach, researchers can collect in-depth and rich data from various perspectives, which are expected to provide a comprehensive picture of the influence of educational media on the development of students' critical thinking skills(Munawwaroh & Putri, 2024).

This study, purposive technique was used in selecting participants. This technique was chosen so that researchers could obtain in-depth information from participants relevant to the study. This study involved 10 participants, consisting of the Principal, Vice Principal of Curriculum, STEM Teachers, and students, taking into account variations in position, educational background, and gender to obtain diverse data.

Table 1. Research informants

Informant	Education	Gender	Amount	Material
Headmaster	S2	L	1	Specific policies that support the use of educational media in STEM learning.
Deputy Head of Curriculum	S1	L	1	Implementation of educational media strategies and curriculum development for STEM.
Teacher	S1	L,P	3	The effectiveness of educational media in improving students' critical thinking skills in the STEM field.
Student	-	L,P	4	Students' perceptions of the impact of educational media on their critical thinking skills in STEM.
Total	4	6	9	-

This study used three main data collection techniques: interviews, observations, and documentation analysis. In-depth interviews with a semi-structured format were chosen to explore in detail the experiences and perceptions of participants regarding the use of educational media in STEM learning and its impact on students' critical thinking skills. Observations were conducted in STEM classes to directly observe the use of educational media and interactions between teachers and students in developing critical thinking(Tahir et al., 2024). In addition, documentation analysis included a review of the curriculum, school policies, and learning materials related to STEM, which helped in understanding the background and objectives of learning.

Data analysis in this study was conducted through three stages adapted from (Miles et al., 2014): 1) Data Reduction. This process involves grouping, selecting, and filtering data to focus on information relevant to the research objectives. 2) Data Presentation. The reduced data is then presented in the form of tables, diagrams, or matrices to facilitate understanding. 3) Drawing Conclusions. Based on the data that has been presented, the researcher interprets the data and draws conclusions that are expected to contribute to knowledge regarding the effectiveness of educational media in building critical thinking in the STEM environment.

RESULT AND DISCUSSION

Result

In the context of developing critical thinking skills in STEM learning environments, strengthening educational policies is key to effectively integrating educational media in educational institutions. Training programs for educators in utilizing educational media for STEM learning, as well as providing adequate technological infrastructure, are important indicators in ensuring successful implementation. In addition, creating a culture of collaboration between educators and students, by involving students in the learning process based on educational media, can increase their active involvement and sense of responsibility for the learning process. By focusing on the development of critical skills and STEM competencies, adaptive policies are expected to improve the quality of learning and prepare students to face complex future challenges.

Interactive Criticality Enhancement

The Increase in Interactive Criticality is an important finding in this study which shows that the use of interactive educational media such as digital simulations, collaborative learning platforms, and visualization applications helps students to be more actively involved in the learning process(Kusnadi & Azzahra, 2024). These media not only encourage students to analyze and evaluate information in depth, but also develop critical thinking skills that are relevant to real-world challenges in the STEM field.

The following interview data shows an increase in interactive criticality at SMAN 1 Paiton Proboinggo:

Table 2. Interview data
increased interactive criticality

Statement	Coding	Informant
"The use of videos and simulations in class makes students more critical in evaluating experimental results."	Evaluation of learning outcomes	Headmaster
"Simulation media helps students understand abstract concepts in a more concrete way."	Concept understanding	Classroom teacher
"With online discussions, students are more confident in expressing their opinions and arguing about the subject matter."	Active involvement	Teacher

"This educational media makes learning less boring and makes me think more critically."	Motivation to learn	Student
"I feel more challenged when I have to find solutions to problems given on the learning platform."	Solution to problem	Student

The table 2 above, it can be understood that interactive educational media encourages students to understand abstract concepts in a more concrete way, providing a deeper and more meaningful learning experience(Gustini & Wulandari, 2020). Through media such as digital simulations and online discussions, students are not only active in expressing opinions and arguing but also show courage in navigating complex ideas, creating a dynamic and motivating learning atmosphere(Javornická et al., 2024). The problem-solving challenges provided by interactive platforms further enhance their engagement, encouraging students to think critically and evaluate learning outcomes in more detail(Yusuf et al., 2024). With these various forms of media, the learning experience becomes more engaging, creating an environment that inspires students to think analytically and reflectively.

Table 2, shows that there are four applications of increasing interactive criticality. Thus, the data as above explains the following findings;

First, Student Involvement: from these findings it shows that the level of student participation in discussions and activities based on interactive educational media that encourage in-depth analysis and reflection on STEM issues.

Second, Problem Solving Skills: that the evaluation of how interactive educational media helps students in identifying problems, designing solutions, and evaluating the results of problem solving.

Third, Development of High-Order Thinking Skills: The influence of interactive media on students' ability to apply STEM principles to think critically, analytically, and creatively in real-world contexts.

Fourth, Improving Concept Mastery: the findings data show the extent to which educational media helps students understand STEM concepts more deeply through more dynamic learning experiences and focus on active involvement.

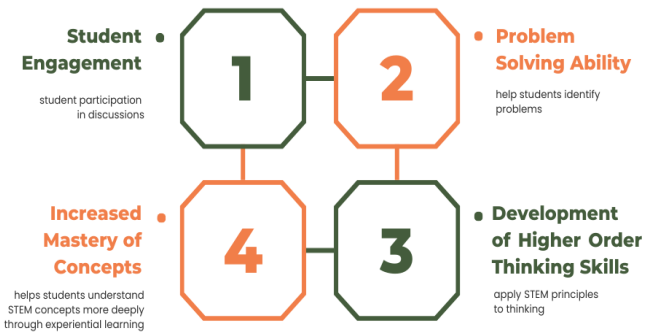

Figure 1. Increased interactive criticality

The picture 1, it is clear that interactive educational media has a significant impact on improving the quality of STEM learning. Student participation in media-based

activities looks more intense, where they are not only actively involved but also encouraged to think more deeply and analytically(Marciano et al., 2024)(Munawwaroh, Qushwa, et al., 2024). In addition, this media supports students in developing their ability to independently develop problem-solving strategies and evaluate the results, a process that is very useful in fostering critical thinking(Onsee & Nuangchalerm, 2019). Interactive media also facilitates the application of advanced thinking skills, allowing students to hone their analytical skills and creativity in contexts that are relevant to real challenges(Munawwaroh, Munir, et al., 2024). Furthermore, the understanding of STEM concepts becomes stronger and deeper, indicating that this learning experience provides students with a solid foundation and is useful for mastering more complex materials.

The Role of Technology Teaching

The Role of Technology Teaching, shows that technology-based educational media can strengthen teachers' abilities in creating interactive and analytical learning environments. Through ongoing training, teachers can design innovative learning that encourages students to think critically. Technology that is well integrated into the STEM curriculum not only enriches teaching methods, but also allows students to explore complex concepts that are relevant to real-world challenges, thereby improving understanding and higher-order thinking skills. As conveyed by the curriculum vice principal of SMAN 1 Paiton, mastery of educational technology is an important part of supporting the STEM learning process. One teacher said, "The use of technology-based educational media helps students understand abstract concepts more realistically." This statement illustrates that the use of appropriate technology can increase students' absorption of STEM materials, especially those that require complex visualizations. Another teacher added, "The technology training we received was very helpful in designing teaching that not only focuses on delivering information, but also encourages students to think critically and analytically." From here we can see how important technology training is to improve teachers' teaching skills.

The statements of several informants above show that teacher competence in educational technology is an essential element in creating an interactive and immersive learning experience(Daugherty et al., 2022). Trained teachers are able to choose educational media that suits students' needs and innovative teaching designs, thus encouraging students to not only receive information but also develop critical thinking skills through in-depth analysis and evaluation(Hacioglu & Gulhan, 2022)(Hasanah et al., 2024). With the support of technology, the STEM curriculum is also increasingly integrated, allowing educational media to play a major role in encouraging understanding of more difficult concepts(Keri & Elbatarny, 2021). Teachers who master educational technology well tend to be more effective in guiding students through a more dynamic STEM learning process.

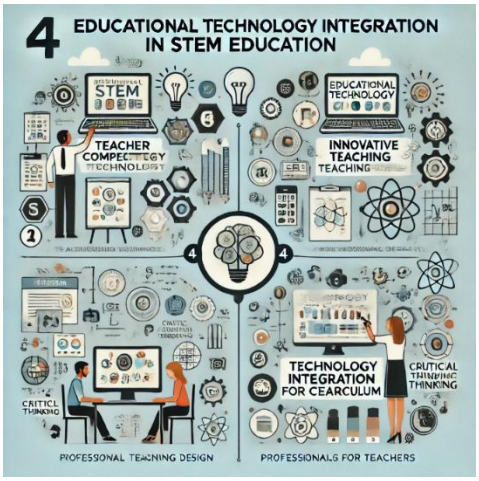

Figure 2. Competency Aspects in Technology Teaching

The findings in the form of the image above, it can be understood that the role of technology teaching in STEM learning in Islamic boarding schools includes several important indicators as follows:

First, Teacher Competence in Educational Technology: Teachers have the skills to choose educational media that is appropriate for STEM learning, which allows students to more easily understand complex material.

Second, Innovative Teaching Design: Teaching is facilitated through interactive media, encouraging students to think critically by analyzing and evaluating STEM concepts.

Third, Teacher Professional Training and Support: Regular training improves teachers' ability to apply technology effectively in learning, helping students hone high-level thinking skills.

Fourth, Integration of Technology in the Curriculum: Educational technology integrated into the curriculum provides space for students to develop critical thinking skills and explore STEM learning in depth.

Thus, these findings emphasize the importance of technology in strengthening the STEM teaching process in Islamic boarding schools, especially through improving teacher competency in educational technology(Starks & Reich, 2023). With adequate technological skills, teachers not only become more effective in delivering materials but also more responsive to students' needs(Munawwaroh, Qushwa, et al., 2024)(Thomas & Sebastian, 2023). Through proper training and ongoing professional support, teachers can design more innovative teaching, create learning environments that stimulate critical thinking, and help students master STEM concepts more thoroughly.

CONCLUSION

The conclusion of this study emphasizes the importance of using technological educational media to shape students' critical thinking skills in STEM learning. The findings of the study indicate that the application of technology in teaching allows teachers to create a more interactive, analytical, and reflective learning environment. With a technology-focused approach, students are encouraged to not only receive information passively but also engage in independent problem solving, design

innovative solutions, and evaluate results that are relevant to real-world challenges.

The scientific contribution of this study lies in new insights into the development of critical thinking skills through the integration of educational media in the STEM curriculum. This study enriches the education and technology literature by showing that teaching approaches that utilize digital media can deepen students' understanding of STEM concepts. This study also emphasizes the importance of teacher training and ongoing support so that teachers have sufficient competence in selecting and optimizing technology according to students' learning needs. With an innovative approach, this study provides a new perspective in improving the quality of STEM learning in educational institutions.

However, this study has several limitations. First, this study was conducted in the context of one or several specific institutions, which may not represent the implementation of technology-based educational media across educational institutions. Second, this study has not deeply evaluated the long-term effects of technology-based teaching on students' critical thinking skills. Third, limitations in the methodological design, such as limited sample size, limit the generalizability of these findings. Therefore, further, broader research is needed to explore the application of technology in STEM learning and comprehensively evaluate its impact in various educational contexts.

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