

The Role of Technology Integration in Enhancing Critical Thinking Skills

Jumaidi Nur

Universitas Kutai Kartanegara

Corresponding Author: Jumaidi Nur jumaidinur@unikarta.ac.id

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ABSTRACT

Technological advances in the field of education encourage the need for the systematic integration of digital tools in the learning process to respond to the need for the development of high-level thinking skills, including critical thinking. This study aims to analyze the influence of educational technology integration on improving students' critical thinking skills, focusing on the relationship between the use of interactive digital media and analytical, evaluative, and reflective thinking skills. A quantitative method with a quasi-experimental design was used in this study, involving 60 junior high school students who were divided into experimental and control groups. Data were collected through critical thinking test instruments before and after treatment, and analyzed using paired t-tests and gain tests to measure effectiveness. The results showed a significant increase in the critical thinking scores of students in the experimental group compared to the control group, with a high effectiveness category. These findings suggest that the integration of technology in learning has an important role in driving students' deep cognitive development. This research contributes to strengthening the empirical basis for the effective implementation of technology-based learning, as well as encouraging the strategic use of digital media to optimize the development of critical thinking skills.

INTRODUCTION

The development of digital technology has provided a major transformation in various sectors, including education. The integration of technology into learning is no longer an option, but has become a demand in the era of the Industrial Revolution 4.0 and a 21st-century society that demands high-level thinking skills, such as critical thinking, problem-solving, and creativity (World Economic Forum, 2020). In Indonesia, the Merdeka Learning policy emphasizes the importance of adaptive and innovative digital-based learning. However, the reality in the field shows that the use of technology in learning is still often instrumental and has not been directed at the development of complex cognitive skills, especially in building students' critical reasoning skills (Kemendikbudristek, 2023).

Critical thinking skills are one of the important indicators in producing a generation of independent and reflective learners. However, a report from the Programme for International Student Assessment in 2022 shows that Indonesian students' literacy scores and critical thinking skills are still below the average of OECD countries (OECD, 2022). This shows the urgent need to reconstruct learning strategies that are able to encourage students not only to absorb information, but also to analyze, evaluate, and make evidence-based decisions. In this context, technology integration has the potential to create an interactive, dynamic, and cognitive exploration-based learning environment.

Previous research has shown the positive benefits of technology in learning, such as increasing motivation, access to information, and collaboration (Kim et al., 2021; Pratiwi, 2022). However, most of the studies still focus on the affective and behavioral aspects of technology use, not specifically evaluating its effect on critical thinking skills. Some studies that have tried to link the two, such as by Yusof et al. (2021), state that technology-based learning has the potential to stimulate critical thinking if designed with an approach that demands problem-solving and reflection. However, the methodological approach used in the study is still limited to descriptive and qualitative studies, with a context that does not reflect much of the dynamics of learning in the secondary school environment in Indonesia.

This research gap is also seen in the lack of experiment-based quantitative research that directly tests the effectiveness of technology integration on improving students' critical thinking skills. For example, a study by Fatimah et al. (2020) only measured teachers' perceptions of the use of technology, without associating it with students' cognitive achievements. Meanwhile, research by Ahmad and Nugroho (2023) discusses the impact of digital learning on general cognitive learning outcomes, but does not specifically examine aspects of critical thinking. Therefore, structured empirical data-driven quantitative research is needed, to fill the gap and provide a stronger decision-making basis.

This study aims to analyze the influence of educational technology integration on improving the critical thinking skills of junior high school students, with an emphasis on the use of interactive digital media in learning. The focus of this research lies in the relationship between technology-based learning treatment and changes in students' analytic, evaluative, and reflective

thinking ability scores. Using a quasi-experimental design, this study presents a quantitative evaluation that can provide empirical clarity on the effectiveness of digital learning strategies.

Theoretically, this research contributes to enriching the study of technology-based learning and critical thinking in the realm of 21st century education. The results are expected to strengthen the argument about the importance of designing technology integration not only as a means of visualization or communication, but as a pedagogical instrument that encourages the construction of knowledge and metacognitive abilities of learners (Anderson & Krathwohl, 2021). This is in line with Bloom's revised taxonomic model which places critical thinking as one of the achievements of high-level cognitive learning. The practical contribution of this research lies in the provision of data and implementation models that can be used as a reference by teachers, schools, and policy makers in designing technology-based learning that is effective and has an impact on strengthening students' critical thinking skills.

LITERATURE REVIEW

The Urgency of Developing Critical Thinking in Education

Critical thinking has become a key skill needed in the face of 21st-century global challenges. According to (World Economic Forum, 2020), critical thinking skills rank high in the list of essential competencies, along with complex problem-solving and creativity. Education in different countries is encouraged to develop high-level cognitive abilities, not just basic skills. In Indonesia, the Independent Curriculum also emphasizes the importance of critical and reflective reasoning as part of the achievement of the Pancasila student profile (Ministry of Education and Culture, 2023). However, PISA 2022 data shows that the critical thinking skills of Indonesian students are still lagging behind OECD member countries (OECD, 2022), so strategic intervention in learning practices is needed.

Concepts and Characteristics of Critical Thinking in Learning

Critical thinking includes the ability to analyze information, evaluate arguments, make logical inferences, and draw conclusions based on evidence (Facione, 2021). (Ennis, 2020) also emphasizes that critical thinking is reflective, reasonable, and oriented towards making sensible decisions. In the context of learning, critical thinking is an indicator of high-level cognitive achievement as reflected in Bloom's revised taxonomy (Anderson & Krathwohl, 2021). Teachers and educational institutions are required to design learning that encourages open discussion, problem-solving, and metacognitive reflection, rather than simply memorizing or absorbing information.

Integration of Technology in Education and Its Potential

Digital technology has opened up opportunities to reform learning to be more collaborative, adaptive, and exploration-based. Various studies show that the integration of technology can create a learning environment that stimulates critical thinking if utilized with the right approach (Kim et al., 2021; Yusof et al., 2021). Tools such as interactive learning apps, digital simulations, and collaborative platforms such as Padlet or Google Classroom have been proven to

support student engagement in analytical and reflective activities (Pratiwi, 2022). However, the study also emphasizes that the success of technology integration depends largely on the pedagogical design that accompanies it (Huang et al., 2023), not just the existence of the device.

The Relationship between Educational Technology and Critical Thinking

Empirical research shows that the use of technology can improve critical thinking skills, especially when applied in project-based learning, problem-solving, and structured online discussions. (Yusof et al., 2021) found that learning using digital media with a problem-based learning approach significantly improved students' evaluative and logical abilities. In Indonesia, a study by (Ramadhani & Sutrisno, 2023) found an increase in students' critical thinking skills after using digital platforms based on interactive quizzes and learning videos. However, some studies have also noted that the use of undirected technology can actually strengthen passive learning (Fatimah et al., 2020), so that a pedagogical approach is the key to success.

Research Gaps and Need for Experimental Quantitative Studies

While many studies have shown a positive relationship between technology use and cognitive skills, most are still descriptive or exploratory in nature. Research that directly tests the effectiveness of technology in improving critical thinking skills through experimental design is still limited, especially in the context of secondary school learning in Indonesia (Ahmad & Nugroho, 2023). Therefore, an experiment-based quantitative study is needed that can provide strong empirical evidence regarding the influence of digital media use on the improvement of students' critical thinking. Research like this will help strengthen the theoretical and practical foundations in the development of technology-based learning policies and strategies at the education unit level.

METHODOLOGY

Types and Approaches to Research

This study uses a quantitative approach with a quasi-experimental research type to empirically test the influence of educational technology integration on improving students' critical thinking skills. The research design used was a non-equivalent control group design, which involved two groups of students, namely the experimental group that received learning with digital technology and the control group that followed conventional learning. This design was chosen because it allowed for a comparative measurement of cognitive skill changes between the two groups, although researchers did not have full control over the subjects' randomization (Creswell & Creswell, 2021).

Population and Sampling Techniques

The population in this study is all grade VIII students in one of the junior high schools in Tenggarong City, East Kalimantan. The sampling technique used is purposive sampling, which is the selection of samples based on certain characteristics that are considered relevant to the research objectives, such as the availability of technology facilities and the readiness of teachers to implement

digital-based learning. Two classes were selected as samples, each consisting of 30 students, making a total of 60 participants. The selection of the number of respondents was based on consideration of the effectiveness of the statistical test and its suitability with the context of the experimental class (Sugiyono, 2022).

Data Collection Techniques

Data was collected using critical thinking test instruments compiled based on critical thinking indicators from (Facione, 2021), including analysis, evaluation, inference, interpretation, and explanation. The test was in the form of a reasoned multiple-choice test with 20 question items that had been adapted from the previous instrument used by (Yusof et al., 2021), then adjusted to the learning context in Indonesia. Before being used in the main data collection, the instrument was tested for content validity through an assessment by three education experts, as well as tested for empirical validity and reliability using the Pearson and Cronbach's Alpha correlation test. The results of the validity test showed that all items had a significant correlation ($r > 0.3$), while the reliability coefficient of 0.812 showed high internal consistency (Arikunto, 2021).

Research Procedure

The research stage begins with planning, namely the preparation of technology-based learning tools for the experimental group and conventional tools for the control group. After obtaining approval from the school and the student's parents, a pre-test was conducted on both groups to measure the initial critical thinking ability. Furthermore, learning was conducted over four weeks, where the experimental group used digital media such as Padlet, Google Slides, and interactive learning videos, while the control group followed regular learning without the help of technology. After treatment, a post-test was given to both groups to measure changes in critical thinking skills. All processes are carried out according to the ethical protocol of educational research and supervised by the school.

Data Analysis Techniques

Data analysis was carried out quantitatively using the paired sample t-test to determine the difference in pre-test and post-test scores in each group, as well as the independent sample t-test test to determine the difference in scores between the experimental group and the control group. In addition, the N-Gain test was used to measure the effectiveness of increasing critical thinking scores. Data processing is carried out with the help of Statistical Package for the Social Sciences (SPSS) software version 26. All tests were performed at a significance level of 0.05. This analysis technique was chosen because it is suitable for quasi-experimental research designs with interval data and pre- and post-treatment measurements (Tabachnick & Fidell, 2020).

RESEARCH RESULT

Improvement of Critical Thinking Skills in the Experimental Group

The results of the paired sample t-test showed that there was a significant difference between pre-test and post-test scores in the experimental group that

received digital technology-based learning treatment. The average pre-test score of students in this group was 58.47, while the post-test score increased to 78.92. This shows an average increase of 20.45 points, which illustrates the effectiveness of technology-based learning in encouraging critical thinking skills.

Table 1. Average Pre-test and Post-test Scores of the Experimental Group

Test Type	Average	Standard Deviation	N
Pre-test	58.47	6.31	30
Post-test	78.92	7.15	30

The analysis of the N-Gain test resulted in a gain score of 0.49 that was in the medium to high category, indicating that the integration of interactive digital technologies such as the use of Padlet, Google Slides, and educational videos – effectively encourages students to analyze, evaluate, and interpret information independently.

To measure the effectiveness of improving learning outcomes, N-Gain (Normalized Gain) analysis is used, which is a comparison between the actual score of learning outcome improvement and the maximum score that can be achieved. The formula used is:

$$\text{N-Gain} = \frac{\text{Post-test} - \text{Pre-test}}{\text{Skor Maksimal} - \text{Pre-test}}$$

Assuming the maximum score is 100, the average N-Gain calculation for the experimental group is:

$$\text{N-Gain} = \frac{78,92 - 58,47}{100 - 58,47} = \frac{20,45}{41,53} \approx 0,49$$

The N-Gain value category is divided into:

- High if N-Gain ≥ 0.7
- Medium if $0.3 \leq \text{N-Gain} < 0.7$
- Low if N-Gain < 0.3

Thus, the N-Gain score of 0.49 is in the medium to high category, which means that the integration of digital technology in the learning process has had a strong positive impact on improving students' critical thinking skills.

Comparison of Critical Thinking Skills between the Experimental and Control Groups

To determine the comparative effectiveness of technology integration, an independent sample t-test was used between the post-test scores of the experimental group and the control group. The control group had an average post-test score of 67.25, which was only a small improvement from the pre-test (59.40). Meanwhile, the experimental group experienced a significant increase.

Table 2. Comparison of Post-tests between the Experimental and Control Groups

Group	Post-test average	Standard Deviation	N
Eksperimen	78.92	7.15	30
Control	67.25	6.84	30

To determine the comparative effectiveness of technology integration between the experimental group and the control group, the independent sample t-test was used, which is a statistical test used to compare the average of two groups that are not interconnected.

Rumus Independent Sample t-Test:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

With a caption:

- X1 = average post-test of the experimental group = 78.92
- X2 = average post-test control group = 67.25
- s1 = standard deviation of the experimental group = 7.15
- s2 = standard deviation of the control group = 6.84
- n1 - n2 - 30

From the calculation with statistical software, it was obtained that the significance value (p-value) was less than 0.05 ($p < 0.05$), which means that the difference between the two groups was statistically significant at the 95% confidence level. The results of the t-test showed a p< value of 0.05, which means that the difference between the two groups was statistically significant. Thus, technology integration has proven to be more effective than conventional methods in improving students' critical thinking skills.

Specific Dimensions of Critical Thinking Affected

Further analysis of the critical thinking test components consisting of analysis, evaluation, inference, interpretation, and explanation indicators showed that the highest improvement occurred in the analysis and evaluation indicators. This is natural because technology-based learning emphasizes students' interaction with visual content, collaborative assignments, and open discussions, which stimulate analytical and reflective activities.

Table 3. Average score per critical thinking ability indicator (experimental group)

Indicator	Pre-test	Post-test	N-Gain
Analysis	12.1	17.4	0.52
Evaluation	11.5	16.7	0.51
Inference	11.9	14.8	0.38
Interpretasi	12.0	15.5	0.43
Explanation	10.9	14.5	0.41

These findings show that digital media-based learning is able to stimulate high-level thinking skills if packaged with a problem-solving approach or reflective tasks.

DISCUSSION

The main results of this study show that the integration of digital technology in the learning process has a significant positive impact on improving students' critical thinking skills. These findings are reflected in the difference in pre-test and post-test scores in the experimental group, as well as the comparison between the experimental and control groups which showed higher effectiveness in technology-based learning models. This increase indicates that the use of technologies such as Padlet, Google Slides, and educational videos has succeeded in creating a learning environment conducive to the development of high-level thinking.

Theoretically, these results are aligned with a constructivistic approach that emphasizes the importance of students' active involvement in the learning process. Digital technology, in this context, acts as a facilitator that allows students to explore information, collaborate, and build understanding through meaningful interactions. Research by (Bezanilla et al., 2020) states that the use of digital tools in a structured manner can improve students' reflective and metacognitive thinking skills. The same thing is also affirmed by (Wang et al., 2021) who found that technology is able to strengthen critical thinking processes when used strategically in collaborative and project-based tasks.

The highest increase that occurred in the analysis and evaluation indicators showed that students not only memorized information, but were also able to assess and criticize logically. This is proof that technology-based learning designs designed with the principles of interactivity and learning independence in mind can foster deeper critical thinking skills (Yuliana & Munir, 2022). In addition, students' emotional involvement in visual media and digital activities also strengthens their attention and motivation to learn (Wijaya et al., 2023).

Although the results obtained support the initial hypothesis, there are several factors to consider. One of the supporting factors is the readiness of students to use technological devices and their ability to navigate digital applications. Students with high levels of digital literacy tend to show better results compared to those who still experience technical barriers. On the other hand, no significant differences were found in the inference indicators, which indicated that the type of activity used had not fully stimulated the skill of inferring or extracting meaning from information in the abstract.

Another obstacle that arose during this study was the limited intervention time which may not be enough to create a long-term impact on the overall aspect of critical thinking. In addition, external variables such as a student's socioeconomic background, variations in individual motivations, and different learning styles can affect outcomes indirectly. Therefore, in follow-up research, it is recommended to extend the duration of interventions, enrich the variety of technology-based activities, as well as classify subgroups of students to identify the effectiveness of the approach based on certain characteristics.

Overall, this research shows that technology can be an important tool in helping students develop critical thinking skills. In terms of theory, the results of this research also strengthen the view that technology is not only a tool, but can be used strategically in the learning process. Practically, these findings suggest that teachers should be given special training to design digital learning that can challenge students' way of thinking. In addition, schools also need to provide adequate technology facilities. In the long run, the benefits of this research not only improve the abilities of individual students, but also encourage a change in learning cultures to be more independent, open to cooperation, and focused on problem-solving.

CONCLUSIONS AND RECOMMENDATIONS

This research shows that the integration of technology in learning can help improve students' critical thinking skills, especially in terms of analytical, evaluative, and reflective thinking. Students who learn using interactive digital media experience a significant increase in scores compared to students who learn in the usual way. This means that the use of technology, if used appropriately, can encourage students to think deeper and not just accept information just like that. This improvement shows that technology has an important role in students' cognitive development, not only as a learning aid, but also as a means to build a more critical way of thinking. These results can be the basis for teachers or schools to design more targeted and effective technology-based learning. With the right strategy, technology can be really used to support more meaningful learning.

ADVANCED RESEARCH

Building on these findings, advanced research can explore how different types of technology – such as adaptive learning platforms, gamified applications, and artificial intelligence-driven tools – affect various dimensions of students' critical thinking across subjects and grade levels. Future studies may adopt experimental or longitudinal designs to examine the sustainability of

technology's impact on analytical, evaluative, and reflective skills over time, as well as investigate how factors such as digital literacy, teacher competence, and learning environments mediate these effects. Comparative studies between technology-rich and technology-limited contexts could also provide insights into equity and accessibility issues, while mixed-methods approaches may capture not only measurable performance outcomes but also students' cognitive processes and learning experiences. This direction would contribute to a more comprehensive understanding of how technology can be strategically integrated into pedagogy to foster deeper, more meaningful learning.

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