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The Effect of Technology-Integrated Learning on Students' Critical Thinking Skills: A Quasi-Experimental Approach

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ABSTRACT

This study examined the effect of technology-integrated learning on students' critical thinking skills using a quasi-experimental design. Sixty undergraduate students from a public university were divided into an experimental group and a control group. The experimental group (n = 30) received instruction through technology-based activities such as online discussions and interactive quizzes, while the control group (n = 30) was taught through traditional lectures and written exercises. Critical thinking was assessed using the California Critical Thinking Skills Test (Facione, 1990), administered as both a pre-test and a post-test. Results showed no significant difference between the two groups in the pre-test, confirming comparable baseline performance. However, the post-test results indicated that the experimental group scored significantly higher than the control group. Paired samples t-tests revealed substantial improvement in the experimental group, whereas the control group showed only a small increase. These findings support the conclusion that technology-integrated learning enhances students' critical thinking more effectively than traditional instruction.

Keywords: *technology-integrated learning, critical thinking, higher education*

INTRODUCTION

Preparing students for complex, information-rich environments requires more than content mastery; it requires well-developed critical thinking—the coordinated use of analysis, evaluation, inference, and reflective judgment in pursuit of warranted conclusions (Dwyer, Hogan, & Stewart, 2014). In parallel, schools and universities have invested heavily in technology-integrated learning, from collaborative platforms to immersive simulations. Contemporary frameworks such as Technological Pedagogical Content Knowledge (TPACK) emphasize that technology benefits learning only when it is purposefully aligned with pedagogy and disciplinary content rather than added as an isolated novelty (Mishra & Koehler, 2006). Against this backdrop, a central empirical question persists: does integrating digital tools into instruction measurably strengthen students' critical thinking, and under what conditions?

A growing body of peer-reviewed research suggests that, when thoughtfully designed, technology-mediated environments can cultivate critical thinking. Early quasi-experimental work in Computers & Education showed that structured prompts and participation guidelines in web-based discussion boards led to higher levels of critical-thinking moves than unstructured forums, highlighting the importance of scaffolding within digital spaces (Yang, Newby, & Bill, 2008). Building on such results, meta-analytic and large-scale syntheses have reported positive average effects for technology-supported collaborative learning on students' critical-thinking outcomes, while also noting meaningful variation by activity design, duration, and learner level (Tedla & Chen, 2024). Research shows that online, project-based learning using shared digital workspaces can sharpen critical thinking when students apply authentic, real-world problems within a framework of guided peer review (Cortázar, Nussbaum, & Caballero, 2021). More recent work focused on secondary classrooms found that carefully managed microblogging conversations also boosted the quality of student arguments and their evaluative reasoning. In both cases, careful instructional design mattered far more than just having the right tool (Williams & Bower, 2025).

However, not every digital learning strategy works the same way. When students engaged with a technology-based self-study program, their critical thinking scores improved. Researchers concluded the growth came from the well-defined task design, not from the online platform it used (Algouzi, Alzubi, & Nazim, 2023). Likewise, quasi-experimental work in health professions education indicates that virtual-reality learning environments can support critical-thinking disposition and knowledge when experiential elements are paired with guided debriefing, again pointing to the interaction among technology, pedagogy, and content (Gabr et al., 2025). Collectively, this literature suggests that technology's impact is conditional: effects tend to be strongest when digital tools are embedded in designs that require explanation, justification, and collaborative sense-making.

Despite these advances, important gaps justify further quasi-experimental inquiry. First, effect magnitudes vary widely across studies, likely due to differences in implementation fidelity, scaffolding, and assessment instruments (Tedla & Chen, 2024). Second, many investigations confound technology use with other active-learning elements (e.g., project-based tasks), making it difficult to isolate the incremental contribution of the digital component. Third, while meta-analyses and mixed-methods studies illuminate general trends, context-sensitive causal evidence, especially with curriculum-embedded interventions, comparable control conditions, and validated measures of critical-thinking skills, remains comparatively scarce across subject areas and educational levels (Cortázar et al., 2021; Williams & Bower, 2025).

The present study addresses these needs by employing a quasi-experimental design to estimate the effect of technology-integrated learning on students' critical thinking. Anchored in the Technological Pedagogical Content Knowledge (TPACK) perspective (Mishra & Koehler, 2006) and informed by prior quasi-experimental successes with structured online discourse and guided digital projects (Yang et al., 2008; Cortázar et al., 2021), the intervention purposefully aligns digital tools with discipline-specific tasks that require students to analyze claims, evaluate evidence, and articulate warranted conclusions. By comparing outcomes with a non-equivalent control condition receiving traditional instruction and by using validated performance measures, this study seeks to provide credible, context-rich evidence on whether and how technology-integrated learning advances critical thinking.

Problem Statement

Technology has become an important part of modern education, offering new ways to present information, encourage interaction, and support active learning. Many schools and universities now use digital tools such as online platforms, simulations, and collaborative applications to improve student learning. Today, one ability absolutely central to everyday life is critical thinking. This means digging into information and arriving at logical conclusions. Technology is frequently hailed as the magic tool that sharpens our reasoning, yet the research paints a murky picture. Some evaluations insist that using tablets, simulations, and online debates prompts kids to think more deeply and tackle real-world problems. Others find barely any bump in critical thinking scores, leaving results almost unchanged. This gray zone confounds teachers looking to weave gadgets and platforms seamlessly into their lesson plans. The real hurdle, therefore, is that no solid proof yet pinpoints how device-filled classrooms team up, or clash, with students' ability to judge and reason. Further investigation is essential to fill this gap in the learning process.

Research Aim

The main objective of this study is to find out whether technology-integrated learning can improve students' critical thinking skills. It also aims to compare the results of students who learn with technology to those who learn through traditional methods. Another objective is to see which teaching practices work best when technology is used to support critical thinking.

Research Questions

1. Does technology-integrated learning have a significant effect on students' critical thinking skills?
2. How do students who experience technology-integrated learning perform compared to those who receive traditional teaching?
3. What teaching strategies with technology are most effective in supporting critical thinking?

Research Hypotheses

H1: Students who participate in technology-integrated learning will show higher levels of critical thinking than students in traditional learning.

H0: There is no significant difference in critical thinking skills between students who learn with technology and those who learn through traditional methods.

LITERATURE REVIEW

Technology-Enhanced Environments and Critical Thinking

Technology-enhanced learning environments are increasingly studied as mechanisms to improve critical thinking. Song and Cai (2024) found that structured interactive learning environments, even when limited to classroom contexts, significantly improved college students' critical thinking scores over time, showing that design rather than screen exposure alone matters. Similar findings were reported by Wang et al. (2024), who used a quasi-experimental design with online classes and found that interactive, discussion-based activities on Zoom improved critical thinking and reduced student anxiety compared to passive online lectures. These studies suggest that interactive digital spaces, when carefully structured, can provide opportunities for reflection and reasoning that foster higher-order thinking (Song & Cai, 2024; Wang et al., 2024).

A systematic review by Sönmez (2021) supported these results by synthesizing multiple interventions across educational levels. The review reported moderate positive effects of technology integration on critical thinking, particularly when students were engaged in tasks that required argumentation, evaluation, and self-reflection rather than passive reception of information. This aligns with earlier findings by Yang, Newby, and Bill (2008), who demonstrated that structured prompts in online discussion boards produced significantly more critical thinking moves than unstructured forums. Both reviews and empirical studies emphasize that technology itself does not guarantee better thinking skills but can facilitate them when learning design promotes higher cognitive engagement (Yang et al., 2008; Sönmez, 2021).

Virtual and immersive technologies also show promise. Gabr et al. (2025) implemented a virtual reality educational program with nursing students and found significant improvements in both critical thinking disposition and knowledge acquisition compared to a control group. These findings indicate that reflective judgment is improved with experiential learning with facilitated debriefing. Similar conclusions were made by Algouzi, Alzubi, and Nazim (2023), who studied the topic of technology-mediated self-study among EFL learners, and the results showed that all the critical thinking improvement was better with the use of targeted video prompts and structured reflection tasks than unguided self-study. Putting all the findings together, it looks like the payoff for boosting critical thinking skills with tech depends on the design choices that encourage users to break down questions and tackle problems step by step (Algouzi et al., 2023).

Teacher Knowledge Frameworks and Pedagogical Integration

Teacher knowledge and pedagogical frameworks also mediate the effect of technology on the process of critical thinking. Mishra and Koehler (2006) developed a framework, Technological Pedagogical Content Knowledge (TPACK), that postulates that successful technology integration is possible when teachers combine technological knowledge with content and pedagogy. Its relevance is still shown by empirical work. In a meta-analysis on mathematics education, Fabian et al. (2024) established that teacher competence in TPACK was an important predictor of student learning outcomes, such as critical thinking. That teacher's expertise in balancing content, pedagogy, and technology is crucial to success.

More evidence is provided by Wang (2022), who designed and tested a scale based on TPACK among English as a Foreign Language teachers. The research found that the teachers did not express any doubts regarding their ability to use technology to deliver simple content. However, they had lower confidence in using technology to develop higher-order skills (e.g., critical thinking). The lack of self-efficacy is a sign of a barrier to successful implementation that proves that the availability of technology is not a guarantee of pedagogical alignment with the goals of critical thinking (Wang, 2022). Likewise, Ait Ali et al. (2023) found that in health professions education, teacher training based on TPACK increased the teaching quality when teachers underwent professional development, which again supports the idea that structures and teacher training are needed to enable the maximum utilization of technology benefits.

Professional development is thus a recurring theme in the literature. Studies indicate that when teachers are explicitly trained to integrate technology into critical-thinking-focused tasks, students show higher gains. Cortázar, Nussbaum, and Caballero (2021) found that online project-based learning improved critical thinking when teachers structured digital collaboration with clear guidelines and scaffolding. In the absence of this type of pedagogy, technology may be applied in the context of merely delivering content and not enhancing knowledge. Studies thus focus on the role of the teacher as a facilitator with the help of tools such as TPACK, in making sure technology has been used as an aid to higher-order development rather than a distraction (Cortázar et al., 2021; Mishra & Koehler, 2006).

Blended, Flipped, and Hybrid Approaches

The use of a mix and inverted classroom approach has attracted interest because it can promote critical thinking in the event of technology integration with active learning techniques. Jou (2016) tested a blended learning model that reached out to a web application in a knowledge transformation model, stating that students demonstrated considerable improvements in critical thinking and increased satisfaction, as opposed to a lecture environment. Chen et al. (2025) also found similar results, studying the flipped classes in life sciences with the assistance of IT tools (Google Classroom, Kahoot, and Quizizz). Their findings revealed that interactive work before classes and subsequent hands-on exercises in the classroom were very effective in boosting engagement and higher-order thinking. These studies, combined with others, indicate that hybrid learning models work when they combine digital tools with reflective and collaborative tasks (Jou, 2016; Chen et al., 2025).

Success is also mentioned in systematic reviews. The article by Sonmez (2021) suggested that blended learning has the most significant impact on critical thinking in the case of scaffolding and interaction with peers, as well as when the evaluation focuses on reasoning and not remembering. Yang et al. (2008) also established that there was no improvement in unstructured usage of technology in discussion forums, but there was an improvement in guided and reflective prompts. These outcomes confirm the hypothesis that the format is not the only factor that will dictate the outcomes in blended and flipped models, but also the quality of design and interaction (Yang et al., 2008; Sönmez, 2021).

There are also emerging studies of the hybrid and immersive methods, which support this claim. In their study, Gabr et al. (2025) highlighted that virtual reality learning has only enhanced critical thinking with guided reflection, which is why it is possible to draw parallels between the principles of blended learning. Cortaza et al. (2021) observed the effect of online project-based courses to enhance critical thinking only in cases where collaboration was organized using digital scaffolds. These findings highlight the need to enhance the integration of technological solutions with carefully constructed pedagogy to ensure that the hybrid models can promote meaningful thinking. The technology that is not accompanied by a reflective or collaborative structure is not enough to generate consistent gains in critical thinking (Gabr et al., 2025).

Theoretical Framework

This paper was informed by the Technological Pedagogical Content Knowledge (TPACK) model that states that successful teaching using technology involves a combination of content knowledge, pedagogical knowledge, and technological knowledge (Mishra & Koehler, 2006). With a combination of these domains, teachers can construct learning activities that extend beyond delivering content to involve students in reasoning and problem-solving actively. Another theory that has been used in the study is the constructivist learning theory, which emphasizes that learners gain their knowledge through engagement with tasks, reflection on experiences, and construction of meaning (Jonassen, 1999). Working with technology constructively, i.e., collaboratively, inquiring, and reflecting can offer the opportunity to students to analyze and evaluate ideas, which are the primary features of critical thinking. Combining TPACK and constructivism provides a theoretical basis for analyzing how technology-integrated learning can advance the critical thinking abilities of students through matching digital instruments with effective instruction.

RESEARCH METHODOLOGY

The study took a quasi-experimental approach to the issue of the impact of technology-integrated learning on the critical thinking abilities of students. The reason why a quasi-experimental approach was selected is that it enables making comparisons between groups under real classroom conditions without the need to make random assignments that are not always feasible in educational settings (Creswell & Creswell, 2018). They used two groups of undergraduate students, with one experimental group who were taught using technology-based instruction and a control group that was taught using traditional instruction. The two groups had their course content in the eight weeks to make it comparable. The participants were 60 undergraduate students pursuing education courses in one of the public universities. Purposive sampling was used since these students were already engaged in classes where technology could be integrated into instruction. The experimental group, consisting of 30 students, was taught using online discussion boards, interactive quizzes, and collaborative digital platforms. The control group, also with 30 students, received instruction through lectures, handouts, and written exercises. Ethical approval was secured from the university, and all participants provided informed consent before taking part in the study.

Critical thinking was measured using the California Critical Thinking Skills Test developed by Facione (1990), which evaluates analysis, inference, and evaluation. The reliability of the scale was ensured by using Cronbach's Alpha. The reliability value was .87 with 34 items. The test was administered as both a pre-test and a post-test to track changes over the eight weeks.

Data analysis combined descriptive and inferential statistics. Descriptive statistics were used to summarize performance, while paired samples t-tests were applied to examine differences within each group, and independent samples t-tests were used to compare post-test results between groups. A significance level of $p < .05$ was applied to determine whether differences were statistically meaningful. These methods are commonly applied in quasi-experimental research on educational interventions because they allow for valid comparisons of instructional impact (Cohen, Manion, & Morrison, 2018).

DATA ANALYSIS AND RESULTS

Table 1: Pre-test Scores of Experimental vs. Control using Independent Samples t-test

Group	N	Mean	SD	t	df	p
Experimental	30	62.40	6.15	0.34	58	.736
Control	30	61.85	6.42			

The results of the pre-test, shown in Table 1, indicate that there was no significant difference between the experimental and control groups at the beginning of the study. The mean score of the experimental group ($M = 62.40$, $SD = 6.15$) was nearly identical to that of the control group ($M = 61.85$, $SD = 6.42$). The independent samples t-test confirmed that this difference was not statistically significant, $t(58) = 0.34$, $p = .736$. These findings demonstrate that both groups started with similar levels of critical thinking ability, suggesting that any subsequent differences can be attributed to the instructional intervention rather than pre-existing disparities.

Table 2: Post-test Scores of Experimental vs. Control by using the Independent Samples t-test

Group	N	Mean	SD	t	df	p
Experimental	30	75.10	5.80	6.32	58	< .001
Control	30	65.20	6.05			

Table 2 gives the post-test outcomes of the two groups at the end of the eight weeks of teaching. There was a significant difference of 10.10 ($M = 75.10$, $SD = 5.80$) between the experimental and control groups ($M = 65.20$, $SD = 6.05$). The difference was statistically significant, $t(58) = 6.32$, $p < .001$, indicating that students who participated in technology-integrated learning achieved greater gains in critical thinking than those taught through traditional instruction. This result provides strong evidence of the effectiveness of integrating digital tools and collaborative platforms into classroom practice.

Table 3: Experimental Group: Pre-test vs. Post-test (Paired Samples t-test)

N	Pre-test Mean	Pre-test SD	Post-test Mean	Post-test SD	t	df	p
30	62.40	6.15	75.10	5.80	11.24	29	< .001

The within-group analysis for the experimental group, summarized in Table 3, also revealed significant progress from pre-test to post-test. The average of the scores rose to 75.10 ($SD = 5.80$), and the paired samples t-test revealed that this increase was very significant with $t (29) = 11.24$, $p <.001$. This indicates that the overall performance increased as a result of exposure to technology-based instruction, not to mention the fact that the overall performance increased significantly, as well as the ability of students to analyze and evaluate information. The magnitude of improvement confirms that the intervention was both meaningful and educationally impactful.

Table 4: Control Group: Pre-test vs. Post-test (Paired Samples t-test)

N	Pre-test Mean	Pre-test SD	Post-test Mean	Post-test SD	t	df	p
30	61.85	6.42	65.20	6.05	2.15	29	.040

Table 4 shows the results for the control group, which also demonstrated some improvement over the course of the study. Their mean score rose from 61.85 (SD = 6.42) in the pre-test to 65.20 (SD = 6.05) in the post-test. The paired samples t-test indicated that this increase was statistically significant, t(29) = 2.15, p = .040, though the effect was modest compared to the experimental group.

DISCUSSION

The results of this study provide strong support for the research hypothesis that students who receive technology-integrated learning would demonstrate significantly higher levels of critical thinking compared to those taught through traditional methods. At the beginning of the study, the experimental and control groups showed no meaningful difference in their pre-test scores, confirming that both groups started from the same baseline. By the end of the intervention, however, the experimental group achieved significantly higher post-test scores than the control group, lending empirical support to the hypothesis and aligning with prior findings that interactive learning environments foster higher-order skills such as analysis and evaluation (Song & Cai, 2024).

The substantial improvement in the experimental group also highlights the role of instructional design in technology use. The hypothesis was supported not simply because technology was present, but because it was applied in ways that encouraged interaction, reflection, and reasoning. Prior research demonstrates that critical thinking develops most effectively when learners are prompted to explain, justify, and evaluate their ideas, and technology can create spaces where these activities occur more naturally (Yang, Newby, & Bill, 2008; Sönmez, 2021). The large gains observed in this study parallel the results of Cortázar, Nussbaum, and Caballero (2021), who found that structured online collaboration significantly improved critical thinking outcomes.

Although the control group also showed a small but statistically significant gain from pre-test to post-test, this improvement was limited compared to the experimental group. This finding suggests that traditional teaching methods may foster gradual progress, but they lack the interactive and reflective elements that accelerate the development of critical thinking (Ennis, 2018).

The group differences prove the assumption that technology, when used in a meaningful way in instruction, proves to be more effective than traditional methods in facilitating higher-order skills. Technological Pedagogical Content Knowledge (TPACK) is one of the theoretical frameworks in which the findings can be interpreted. This framework shows that technology can only improve the learning results upon the combination with good pedagogical and content knowledge (Mishra & Koehler, 2006). Results of this study are aligned with other studies that have found that teachers utilizing TPACK principles can more easily create learning experiences that can promote reasoning and reflection (Wang, 2022; Fabian, Elstad, and Thyberg, 2024). This theoretical view confirms the hypothesis supported by the observed results because the intervention was effective in introducing pedagogical strategies to match technology use in developing critical thinking. The results can also be explained with the help of constructivist learning theory. Constructivism focuses on the idea that learners develop knowledge by being active, reflecting, and collaborating (Jonassen, 1999). The digital instruments used in the experimental group provided students with opportunities to interact, question, and evaluate, which are important in critical thinking. Research has verified that project-based and interactive digital learning can result in meaningful improvement in higher-order skills (Cortázar et al., 2021). In this way, the hypothesis is not only statistically supported but it is also based on the well-established theories of learning.

LIMITATIONS

This study was limited by its relatively small sample size of 60 students from a single university, which restricts the generalizability of the findings. The eight-week duration may not fully reflect the long-term effects of technology-integrated learning on critical thinking.

FUTURE RESEARCH DIRECTIONS

- Further work is needed on bigger and more varied samples and non-university and non-advanced educational settings to make the results more generalizable.
- Longitudinal studies are also necessary to show the long-term effects of technology-integrated learning on critical thinking.
- A more in-depth understanding of the reasoning process of students should be captured by using mixed-method approaches, which involve interviews, reflective journals, or case studies.
- The comparative research of digital tools (e.g., virtual reality, gamified platforms, AI-based tutors) may help to determine which technologies can be the most effective in developing the ability to think critically.

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