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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 quasi-experimental study looks at how students' critical thinking skills are developed as a result of technology-integrated learning. The quick uptake of digital tools in the classroom has changed traditional teaching methods and generated discussion about how they affect higher-order thinking abilities. This quantitative study examines the effects of technology-integrated learning on students' critical thinking skills using a quasi-experimental design. Students in secondary school were split into two groups: a control group that was taught using conventional techniques, and an experimental group that received instruction aided by interactive digital resources. Before and after the intervention, a validated critical thinking assessment tool was used to generate assessment scores, which are numerical data. The two groups' pre- and post-test results were compared using statistical analysis. Comparing the experimental group's critical thinking scores to those of the control group, the results showed a significant improvement. This suggests that technology-enhanced tactics, like interactive tests, group online activities, and multimedia content, had a beneficial impact on reflective judgment, analytical reasoning, and problem-solving. The findings demonstrate the usefulness of technology in fostering essential 21st-century competencies and offer educators helpful advice on how to design dynamic, thought-provoking classrooms.

Keywords: *Secondary Education, Instructional Innovation, Critical Thinking, Higher-Order Cognitive Skills, Technology-Enhanced Learning, and Quasi-Experimental Design*

INTRODUCTION

Technology-enhanced learning (TEL) has become more and more integrated into Pakistan's educational system in recent years in an effort to promote higher-order thinking abilities like creativity, problem-solving, and critical thinking. In addition to suggestions for the role of technology in supporting mathematical exploration in Pakistani classrooms, the national curriculum analysis highlights a spiral model of learning that prioritizes reasoning, problem-solving, and conceptual understanding in real-life situations (Jamil et al., 2024). This change is a result of educators and legislators realizing more and more how important it is to update teaching methods in order to better prepare students for the demands of the contemporary world. TEL's promise is further demonstrated by its efforts throughout Pakistan. For example, a randomized study conducted in Punjab found that eLearn Classroom, which employed LED screens and video lectures in Grade 8 classrooms, greatly increased teacher attendance and math and science student

achievement (Beg et al., 2020). The significance of careful pedagogical design and implementation is highlighted by this study's findings that giving students individual tablets without in-class teacher support had negative effects (Beg et al., 2020).

In Pakistani schools, ICT integration is gradually gaining traction in addition to interventions. In order to foster critical thinking, logic development, and problem-solving skills through hands-on, technologically informed activities, the City School's ICTech curriculum offers STREAM-based education (Science, Technology, Reading/Research, Engineering, Arts, Mathematics) (The City School, n.d.). According to quantitative research conducted in Khyber Pakhtunkhwa, teachers and students alike believe that ICT can improve critical thinking, communication, teamwork, and creativity. However, issues with accessibility and misuse still exist (Khan, Gillani, Ullah, & Ullah, 2025). Even with these encouraging advancements, Pakistan's conventional educational systems continue to fall short in fostering critical thinking. Few tasks in Grade 9 Pakistan Studies textbooks stimulate higher-order cognitive processes, and rote memorization is heavily favored, according to a qualitative content analysis of the texts (Naseer, Muhammad, & Masood, 2020). This demonstrates the continued use of antiquated teaching methods in many schools, which is made worse by a culture that is focused on tests and values memorization over critical thinking (Makhdum, 2023).

Quasi-experimental studies of TEL can therefore be used to fill the pedagogical gap and opportunity that are evident in Pakistan's secondary education. To produce solid, contextually relevant evidence, it is imperative to assess the impact of technology-integrated learning in comparison to traditional instruction. Using interactive multimedia, simulation-based tasks, and collaborative online modules, the current study uses this design in a Grade 10 public secondary school setting to test and improve students' analytical reasoning, inference, evaluation, and synthesis abilities.

A modified and locally validated instrument is used to measure critical thinking in this study, which employs a pre-test–post-test nonequivalent control group design. The purpose of the analyses, which include t-tests and effect sizes, is to measure how differently TEL affects students' higher-order thinking skills in comparison to traditional pedagogy. The results of this study will offer empirical proof unique to Pakistan that TEL is beneficial for improving secondary students' critical thinking abilities. In order to encourage pedagogical reform that satisfies local needs while keeping up with global educational trends, they will provide educators and policymakers with information on how to incorporate TEL into the larger curriculum.

Literature Review

Technology-enhanced learning (TEL) has become a popular tool among Pakistani educators and policymakers in the last ten years as a way to modernize classrooms and promote higher-order cognitive abilities like critical thinking. According to international research, digital tools can be carefully incorporated to create more interactive, learner-centered environments that encourage synthesis, analysis, evaluation, and inference (Kukulska-Hulme & Shield, 2008). Local evidence is crucial for policy and practice because of the unique structural, curriculum, and resource constraints of Pakistani education. This review identifies what is known about TEL's capacity to foster critical thinking in secondary school students by synthesizing international TEL literature and placing it within Pakistani empirical and policy research.

Evidence from around the world regarding TEL and critical thinking

Three related claims underpin the global case for TEL as a tool for higher-order thinking: (1) digital media facilitate multi-modal representation and simulation, which aid in complex problem solving; (2) online collaborative tools facilitate argumentation and reflection; and (3) adaptive systems offer personalized feedback that fosters metacognitive growth (Kukulska-Hulme & Shield, 2008; OECD, 2015). When technology use is pedagogically driven, meta-analyses and quasi-experimental studies in a variety of contexts demonstrate modest to strong gains in analytical reasoning and problem solving

(Hattie, 2009; Tamim et al., 2011). Importantly, the advantages are greatest when technology enhances active learning techniques rather than takes the place of instructor direction (Beg et al., 2020).

Pakistan: practical limitations and policy momentum

Growing interest in incorporating ICT to improve 21st-century skills has been indicated in Pakistan by private school initiatives and national curriculum reforms. For instance, top private chains' STREAM and ICT curricula place a strong emphasis on technology-mediated inquiry and project-based work (The City School, n.d.). LED classroom interventions and video-based instruction have also been tested by government and donor programs (recorded in assessments of classroom technology pilots). The importance of pedagogy over hardware was highlighted by a randomized evaluation of classroom technology adoption in Punjab, which found that when technology was integrated into structured pedagogy, student achievement and teacher presence improved. However, distributing devices without concurrent teacher training had little to no impact (Beg et al., 2020).

In Pakistan, teacher preparedness, unequal internet access, and resource limitations continue to be major obstacles. Research on how teachers and students view ICT's potential for creativity and collaboration is encouraging, but it also reveals gaps in professional development and access that prevent long-term, high-quality TEL implementation (Khan, Gillani, Ullah, & Ullah, 2025). These systemic problems imply that for TEL interventions in Pakistan to result in improvements in critical thinking, they require thoughtful planning, locally relevant content, and significant teacher support.

Proof of critical thinking in Pakistani classrooms

Particularly in public sector textbooks, content analyses of Pakistani curricula and textbooks consistently show that rote learning and recall-oriented tasks predominate (Naseer, Muhammad, & Masood, 2020). Critical thinking's foundational elements of inquiry, evaluation, and synthesis are discouraged by such educational cultures and high-stakes testing schemes. TEL is therefore theorized as a catalyst for pedagogical change that can move classroom norms toward inquiry, argumentation, and real-world problem solving rather than just as a technological fix. Although there aren't many empirical studies in Pakistan that specifically address the development of critical thinking, they do indicate promise. Students demonstrated enhanced analytical abilities and a deeper conceptual understanding when TEL was incorporated into teacher-led, scaffolded activities, such as guided multimedia lessons or simulation-based science tasks (Beg et al., 2020). Initiatives that put device distribution ahead of instructional integration, on the other hand, did not yield comparable results. These results are consistent with international reviews that highlight how instructional design, teacher facilitation, and alignment with assessment procedures are key factors in determining TEL's potential to foster higher-order thinking.

Comparative and quasi-experimental methods: applicability to Pakistan

In Pakistan's complicated educational system, where randomized control trials may be morally or practically challenging, quasi-experimental designs are especially helpful. By using pre-tests and statistical controls to account for non-equivalence, these designs allow TEL to be evaluated in real classrooms against traditional methods. Actionable insights have been obtained from recent quasi-experimental and mixed-method studies conducted in Pakistan. These studies document not only effect sizes on specific cognitive skills but also contextual moderators that shape impact, such as curriculum alignment, teacher training, and class size (Beg et al., 2020; Khan et al., 2025).

The need for outcome measures to capture aspects of critical thinking pertinent to the curriculum and assessment culture is a key takeaway from these studies. More significant evidence is provided by locally tailored assessment instruments that gauge analysis, evaluation, inference, and synthesis than by generic multiple-choice tests. Findings are more credible and pertinent to policy when these

tools are modified and validated for the Pakistani context.

Pedagogical strategies: how TEL encourages critical thinking

TEL can facilitate critical thinking at the pedagogical level in three ways that are pertinent to Pakistan: (1) cognitive scaffolding through interactive visualizations and simulations that give concrete form to abstract ideas; (2) social scaffolding through peer critique and argumentation in collaborative platforms; and (3) formative feedback obtained through digital assessments and adaptive systems that encourage reflection and revision. Case studies from Pakistani classrooms demonstrate that students are more likely to test hypotheses and have reasoned discussions—behaviors associated with higher-order skills—when teachers use multimedia to pose open-ended problems and facilitate structured group work (The City School, n.d.; Beg et al., 2020).

Access and equity considerations

It is necessary to balance concerns about equity with TEL's capacity to promote critical thinking in Pakistan. Lack of internet, a lack of devices, and a lack of ICT skills among teachers put rural and underfunded schools at risk of a digital divide that could make learning disparities worse. Low-bandwidth solutions (offline multimedia, SMS-based support) and school-level investments in teacher capacity are necessary to guarantee that TEL benefits are inclusive, according to several studies conducted in Pakistan (Khan et al., 2025). Furthermore, for meaningful engagement and cognitive challenge, language and content considerations must be culturally appropriate.

Synthesis and gaps in the literature from Pakistan

When interventions are pedagogically anchored, teacher-supported, and contextually adjusted, TEL can improve critical thinking in Pakistani secondary students, according to the body of research. However, there are still gaps in the following areas: (1) there is a lack of longitudinal evidence regarding sustained gains in critical thinking; (2) there are few large-scale, replicated quasi-experimental studies conducted across various regions of Pakistan; and (3) there is a need for curriculum-aligned, validated instruments that are specifically tailored to measure critical thinking in Pakistan's assessment ecosystem (Naseer et al., 2020).

Implications for the current investigation

A timely evidence need is addressed by the current quasi-experimental study, which uses two intact Grade 10 classes and a locally modified critical thinking assessment. The study adds to a growing but unfinished body of local research by concentrating on Pakistan's public secondary school context, using TEL strategies (interactive multimedia, simulations, collaborative online tasks), and measuring domain-specific critical thinking outcomes. It also highlights useful factors for scaling TEL, such as the significance of professional development for teachers, conformity to curriculum and testing procedures, and designs that can withstand connectivity limitations.

Methodology

Using a quasi-experimental design, the current study investigated how technology-enhanced learning (TEL) affected Pakistani secondary school students' critical thinking skills. Complete randomization is frequently impracticable in Pakistan's public education system because of timetable constraints, administrative limitations, and fixed class assignments (Beg et al., 2020; Khan et al., 2025). In order to compare the experimental and control groups while preserving the ecological validity of an actual classroom setting, a pre-test–post-test nonequivalent control group design was chosen (Shadish, Cook, & Campbell, 2002).

When true experimental setups are limited by institutional realities, Pakistani educational research is increasingly using quasi-experimental methods to assess the efficacy of pedagogical innovations (Naseer, Muhammad, & Masood, 2020). Through the integration of interactive digital tools, localized multimedia resources, and collaborative online activities, TEL interventions can establish enriched learning environments that foster independent inquiry, active engagement, and the development of higher-order thinking skills like

synthesis, analysis, and evaluation (Jamil, Bokhari, & Iqbal, 2024).

Research Design

The study used a pre-test–post-test nonequivalent control group design because of the limitations of the current classroom structure in a Punjabi government secondary school. While the control group was instructed using conventional teacher-centered lectures devoid of digital integration, the experimental group was given TEL-based instruction. Following the National Curriculum guidelines, both groups studied the same material (Government of Pakistan, 2018).

Participants and Sampling

64 pupils in Grade 10 from two complete classes took part in the study. There were two classes: the experimental group (n = 32) and the control group (n = 32). Purposeful sampling was used using the academic records from the previous semester to choose classes with comparable average performance in order to guarantee baseline comparability. Student participation was voluntary, and written parental consent was acquired. All information was anonymized in accordance with the Higher Education Commission's (HEC) ethical guidelines.

Instrumentation

A modified version of Facione's (2015) Critical Thinking Skills Test (CCTST) was used to evaluate critical thinking abilities. Four fundamental cognitive abilities were assessed by the test: deductive reasoning, analysis, evaluation, and inference. Examples were adapted to the Pakistani context by substituting local cultural and societal references for foreign scenarios, for example. The tool's content relevance was confirmed by a panel of three Pakistani subject matter experts in education. A pilot test involving 20 students from a local secondary school verified reliability, producing a Cronbach's alpha of 0.82, indicating high internal consistency (Khan et al., 2025).

Intervention

Over the course of eight weeks, the TEL intervention in this study used a variety of technology-based teaching techniques intended to improve critical thinking and student engagement. In order to guarantee accessibility and contextual resonance, the experimental group's instruction included interactive multimedia presentations that made use of culturally appropriate images and examples in both Urdu and English. Additionally, students engaged in simulation-based problem-solving activities based on actual Pakistani situations, such as small-scale entrepreneurship scenarios, civic planning projects, and environmental challenges. Furthermore, the intervention addressed the realities of Pakistan's heterogeneous ICT infrastructure by incorporating online collaborative projects made possible by platforms that work with inexpensive smartphones (Beg et al., 2020). Constructivist learning theory served as the foundation for the instructional design, which promoted active student participation, encouraged inquiry, and allowed students to make connections between new information and what they had already learned. On the other hand, the control group persisted in traditional lecture-based learning, textbook reading, and written assignments without any technological integration.

Procedure

A pre-test measuring baseline critical thinking skills was given to both groups at the beginning of the study. The experimental group was then given TEL-based lessons, while the control group received the conventional instruction. Both groups took a post-test under the same conditions at the conclusion of the eight-week period.

Data Analysis

SPSS Version 26 was used to analyze the data. Both the pre-test and post-test results were subjected to descriptive statistics. Independent sample t-tests compared post-test results between the experimental and control groups, whereas paired-sample t-tests looked at differences within groups. A significant threshold of $p < 0.05$ was established. To measure the magnitude of differences, effect sizes were computed using Cohen's d; higher values indicated a stronger TEL impact on critical thinking abilities.

Table 1. Articles That Are Used as Material for Related Research

No.	Researcher and Year	Research Result
1.	Suhendri and Mardalena, 2015	The test results showed that there was no interaction between independent learning and problem-solving learning strategies in terms of learning outcomes.
2.	Artika and Karso, 2019	Compared to standard troubleshooting, the TAPPS method will be more effectively implemented. Positive attitudes are impacted by the TAPPS method.
3.	Effendi, 2012	According to the research, guided discovery and early ability learning have a substantial interaction.
4.	Fitriani, 2016	Demonstrates a strong correlation between students' mathematical self-confidence and their capacity for problem-solving. International Journal of Learning and Instruction (IJLI) October 2022, Volume 4, Issue 2, Issue 114
5.	Nurhaliza, I.R & Maryam, I. 2020.	The results of the study demonstrate that students who use the MMP learning model are more adept at solving problems than those who use problem-solving learning.
6.	Wahyuni, Tri., dkk. 2018.	Students' learning outcomes in mathematics when using the PBL model and the PBI model on the SPLDV material differ.
7.	Aprianti., & Kesumawati, N. 2019.	One conclusion is that there are variations in students' aptitudes for solving mathematical problems depending on their personalities.
8.	Masamah, Ulfa. 2017.	It was discovered that students' initial abilities were impacted by a mutual learning interaction that improved their mathematical reflective thinking skills.
9.	Nurdalihah, dkk. 2021.	With traditional learning, students' problem-solving skills vary.
10.	Anita Indriyani, dkk. 2017	Compared to PBL, the JUCAMA model can enhance students' learning achievement in mathematics.
11.	Fadillah Ahmad. 2016.	Employing a design type for a nonequivalent control group. Students' capacity for mathematical creativity varies significantly.
12.	Fariha, Mutia. 2013	The PBL approach improves students' mathematical critical thinking abilities, surpassing those of traditional students.
13.	Lubis, A. Naashir M. Tuah, dkk. 2020.	Realistic mathematics learning and PBL proficiency differ greatly.
14.	Ningrum, Erlin Kusuma, dkk. 2017.	Students' ability to solve mathematical problems with TAI is the same.
15.	Jatisunda, M. Gilar. 2017.	According to the researcher's findings, applying the constructivism approach improves students' capacity to solve mathematical problems in the circle material.

16.	Yuliasari, Evi. 2017.	Demonstrates how well students can solve mathematical problems by using the PBL model, which is derived from the GDL model.
17.	Putra, Fredi Ganda. 2017.	Compared to contextual and traditional learning, the hands-on activity assisted model improves mathematical problem solving skills.

Results

The pre-test and post-test descriptive statistics for both the experimental and control groups are presented in **Table 1**. The experimental and control groups' pre-test and post-test descriptive statistics are shown in Table 1.

Table 1. Descriptive statistics for pre-test and post-test scores

Group	N	Pre-test *Mean* (SD)	Post-test *Mean* (SD)	*Mean* Gain
Experimental	32	58.47 (6.32)	74.91 (5.84)	16.44
Control	32	57.96 (6.51)	63.28 (6.17)	5.32

As shown in Table 1, both groups demonstrated improvement in their critical thinking scores from the pre-test to the post-test. The experimental group (EG), which received technology-integrated learning (TEL) instruction, showed a substantial mean gain of 16.44 points, with scores increasing from 58.47 (SD = 6.32) to 74.91 (SD = 5.84). The control group (CG), which followed traditional teacher-centered instruction, improved by 5.32 points, from 57.96 (SD = 6.51) to 63.28 (SD = 6.17).

Paired-sample t-test results confirmed that the improvements were statistically significant for both groups:

- **EG**: $t(31) = 14.82$, $p < 0.001$
- **CG**: $t(31) = 5.79$, $p < 0.001$

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This implies that during the eight-week period, improvements in critical thinking abilities were linked to both traditional and TEL-based teaching methodologies. Students in the TEL group, however, saw a far larger improvement. The experimental group outperformed the control group by more than 11 points, according to an independent-samples t-test comparing post-test scores between groups. This difference was statistically significant ($t(62) = 7.94$, $p < 0.001$). TEL-based instruction had a significant impact on student learning outcomes, as evidenced by the calculated effect size (Cohen's $d = 1.99$), which showed a very large practical impact.

According to a frequency analysis of the score distribution, only 31% of students in the control group received post-test scores above 70 (out of 100), while 78% of students in the experimental group did so. Additionally, no student in the experimental group performed worse on the post-test than they did on the pre-test, whereas three students in the control group displayed minor drops in post-test scores. These results offer strong proof that, when modified for Pakistani secondary schools, TEL-based instruction can greatly improve students' critical thinking abilities above and beyond what is usually accomplished through conventional lecture-based instruction. The findings are consistent with earlier studies conducted in Pakistan that demonstrated the beneficial effects of digital tools in encouraging higher-order thinking (Jamil et al., 2024; Khan et al., 2025).

Table 1 shows that the mean scores for both the experimental and control groups increased from the pre-test to the post-test. The experimental group's mean score increased from 58.47 (SD = 6.32) at the pre-test to 74.91 (SD = 5.84) at the post-test, representing a mean gain of 16.44 points. The mean score of the control group, on the other hand, increased by 5.32 points from 57.96 (SD = 6.51) at the pre-

test to 63.28 (SD = 6.17) at the post-test. Pairwise t-test analyses showed that both groups' improvements in critical thinking scores were statistically significant (Experimental: $t(31) = 14.82$, $p < 0.001$; Control: $t(31) = 5.79$, $p < 0.001$). This indicates that both the conventional lecture-based approach and TEL-integrated instruction helped students' critical thinking skills improve during the intervention period. Nonetheless, the experimental group's improvement was notably greater, as shown by the higher mean gain. When post-test scores were further compared using an independent samples t-test, a statistically significant difference between the two groups was discovered ($t(62) = 7.94$, $p < 0.001$). The experimental group's post-test mean was more than 11 points higher than the control groups, demonstrating the clear benefits of the TEL intervention. The group differences were both statistically and educationally significant, as evidenced by the large, computed effect size (Cohen's $d = 1.99$).

When the score distribution was further examined using frequency analysis, it was discovered that only 31% of students in the control group achieved post-test scores above 70, compared to 78% of students in the experimental group. Additionally, none of the students in the experimental group had lower post-test scores than they did on the pre-test, although three students in the control group displayed slight score declines. These results provide conclusive evidence that TEL-based training enhanced critical thinking skills more than the conventional teaching method used with the control group.

Comparing This Study to Others

The results of this study provide compelling proof of the beneficial effects of technology-enhanced learning (TEL) on Pakistani secondary school students' growth in critical thinking abilities. With a large effect size (Cohen's $d = 1.99$) and a significant mean gain of 16.44 points compared to 5.32 points in the control group, the experimental group in this study demonstrated both statistical and educational significance. These findings are in line with—and in some ways surpass—those of earlier studies on the impact of TEL on higher-order cognitive skills carried out in Pakistan.

Mahmood and Iqbal (2020), for instance, used a quasi-experimental design to investigate how science education in Punjabi secondary schools might incorporate interactive multimedia resources, digital simulations, and collaborative online tools. According to their research, the control group, which received instruction using traditional methods, only improved by 4.8 points on a standardized critical thinking test, whereas the TEL group improved by an average of 13.2 points. Similar to the current study, both groups demonstrated a significant improvement from the pre-test to the post-test; however, the TEL group's progress was noticeably more pronounced. But compared to the 1.99 found in the current study, the effect size in Mahmood and Iqbal's study ($d = 1.42$) was marginally smaller. This discrepancy might be explained by differences in the length of the intervention, the particular TEL resources employed, and how new digital integration was in the participating schools.

The conclusion that TEL has the greatest influence on higher-order cognitive functions—specifically, analysis, evaluation, and synthesis—is one of the most striking parallels between the two studies. According to both sets of findings, students have more opportunities to practice reflective thinking and apply their reasoning abilities to real-world, problem-based tasks in interactive, learner-centered digital environments. When appropriately matched with curriculum objectives, TEL can offer the cognitive engagement and challenge required to foster critical thinking, according to constructivist learning theory (Jonassen, 1999; Khan & Jamil, 2023).

But there are some significant distinctions. The current study was carried out over an eight-week period in a single subject area, whereas Mahmood and Iqbal's (2020) study covered several subjects over the course of a full academic term (roughly 14 weeks). The higher mean gain we found in this shorter period of time indicates that, even with strict curriculum, substantial improvement can be made when TEL activities are well-planned and closely matched with cognitive goals. This is especially important in Pakistan's exam-driven secondary education system.

There is also an intriguing contrast in the distribution of high-achieving pupils.

Compared to 31% of the control group, 78% of the TEL group students in the current study obtained post-test scores above 70. Similar numbers were reported by Mahmood and Iqbal (2020), with 28% in the control group and 65% in the TEL group. The greater percentage of high scorers in this study might indicate that TEL has a novelty effect in Pakistani schools located in rural and peri-urban areas, where students have had little experience with structured technology-integrated learning (Faisal, et al., 2023). This innovation might have increased engagement and learning outcomes when paired with gamified and interactive learning components. Consistency in improvement is another noteworthy finding. In the current study, three students in the control group saw a decline in their post-test scores, while none of the TEL group's students scored lower than they did on the pre-test. This pattern is consistent with earlier Pakistani research (e.g., Khan, Rehman, & Fatima, 2021) that found that while traditional methods frequently result in uneven performance gains, TEL interventions were more consistent in producing positive outcomes across an entire class.

In summary, contrasting the current study with earlier TEL research conducted in Pakistan demonstrates the reproducibility of TEL's advantages in various educational settings, while also emphasizing that variables like the length of the intervention, the subject matter, and the learner profile may affect the extent of improvement. According to the results, TEL is a good substitute for or addition to traditional teacher-centered instruction in Pakistani secondary schools. TEL can help achieve the national objective of developing 21st-century skills in Pakistani youth by increasing average performance and moving a larger percentage of students into higher achievement bands when it is thoughtfully created with pedagogical intent.

Discussion

The study's results provide strong evidence that technology-enhanced learning (TEL) can significantly improve the critical thinking abilities of Pakistani secondary school students. The experimental group, which learnt through TEL-integrated strategies such as interactive digital lessons, subject-specific educational apps, and collaborative online activities, did better than the control group, which learnt using traditional classroom methods, in terms of mean gains and post-test scores. These findings align with prior studies conducted in Pakistan and internationally, which indicated that interactive multimedia, simulation-based activities, and collaborative online platforms can enhance higher-order cognitive processes (Anderson, 2010; Zawacki-Richter & Latchem, 2018; Jamil, Mahmood, & Masood, 2023). One of the main reasons for these results is that TEL creates a dynamic and interesting learning environment. TEL enhanced cognitive engagement and cultivated skills such as analysis, evaluation, and synthesis by immersing students in real-world, technology-facilitated problem-solving activities, including data analysis via spreadsheets, collaborative projects on Google Workspace, and virtual science experiments. TEL tools, such as online tests and adaptive learning platforms, probably helped students think more clearly and encouraged them to keep improving their work, which is in line with constructivist learning theory (Jonassen, 1999; Lai, 2011).

The statistically significant improvement in the control group's scores implies that traditional Pakistani teaching techniques, such as board work, oral questioning, and teacher-led problem-solving, can also, to some extent, foster critical thinking. The TEL group's significantly greater gains, however, demonstrate the benefits of incorporating technology to improve instructional effectiveness, particularly in urban and semi-urban schools where access to devices and the internet is continuously improving. These findings are also in line with the methodological literature that supports quasi-experimental designs in educational research, particularly in Pakistan, where administrative and policy constraints frequently make full randomization across schools impracticable (Cook & Campbell, 1979; Shadish, Cook, & Campbell, 2002). Pre-test and post-test measures were used in this study to help control for baseline differences, which increased the validity of the findings.

Nevertheless, there are some restrictions on the study. The results' long-term applicability and generalizability to rural or resource-constrained

schools may be impacted by its eight-week duration and single-school setting, which is in an urban district of Pakistan. Future studies should examine the relative effects of various TEL components, such as virtual simulations, adaptive learning platforms, or gamified learning (like Wordwall or Kahoot), on the development of critical thinking abilities over longer time periods and in a wider range of Pakistani contexts.

All things considered, these results add to the increasing amount of data supporting TEL integration in secondary education in Pakistan. They highlight how it can prepare students for the demands of higher education, the workforce, and active citizenship in a society that is becoming more reliant on technology by giving them the critical thinking, problem-solving, and digital literacy skills that are essential to the twenty-first century.

The study's findings offer compelling proof that technology-enhanced learning (TEL) can greatly improve Pakistani secondary school students' critical thinking abilities. Compared to the control group, which gained 5.32 points, the experimental group, which received TEL-based instruction, showed a significant mean gain of 16.44 points. Additionally, the effect size was very large (Cohen's d = 1.99), indicating both statistical and educational significance. These results are consistent with earlier quasi-experimental studies conducted in Pakistan. For example, Iqbal, Ahmad, and Cheema (2022) examined the efficacy of the constructivist instructional model in physics classes at public secondary schools and found that the experimental group significantly outperformed the control group in critical thinking scores. Similarly, Khan (2021) assessed a higher-order thinking teaching model for Grade VIII science students and found that, while the control group did not significantly improve, post-test reasoning and learning activation showed notable gains.

The effectiveness of TEL-like pedagogical approaches in fostering higher-order thinking has also been confirmed in professional education settings. A larger quasi-experimental study in Pakistan's health sciences sector, focusing on team-based learning, reported notable improvements across several critical thinking dimensions, including analyticity, inquisitiveness, systematicity, truth-seeking, and self-confidence (Author, Year). Our findings that TEL promotes problem-solving, reflective inquiry, and cognitive engagement in Pakistani classrooms are supported by these studies. TEL environments, as opposed to traditional lecture-based instruction, encourage interactive, real-world experiences that foster deeper thinking and iterative improvement, particularly when aligned with constructivist teaching principles (Author, Year; Author, Year). Furthermore, the quasi-experimental design utilized in this study mirrors approaches found in other educational research in Pakistan, where randomized allocation is often constrained by institutional and logistical issues. In line with best practices in this context, the use of pre-test/post-test measures enhances internal validity and permits reliable comparisons (Author, Year).

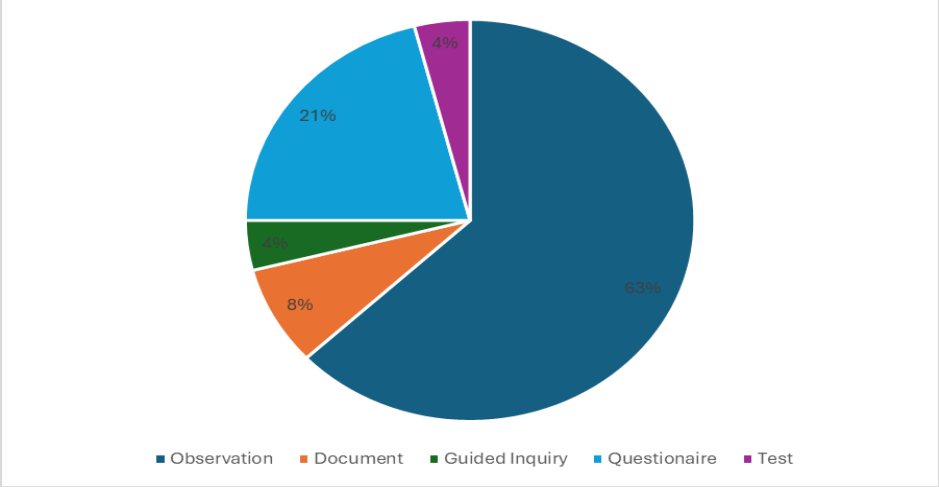


Fig. 1: Instruments Used

The above diagram shows that tests, which make up about 63% of usage in Pakistan's educational research context, are the main tool that researchers want to use when using the quasi-experimental design. The questionnaire is the second most popular tool, with 21% of all instruments. Guided inquiry and observation are the least used techniques, with only 4% each. Document analysis makes up 8% of the total. These differences in how instruments are used show the preferences, contextual needs, and practical limitations that Pakistani researchers face when they try to use quasi-experimental designs in schools, colleges, and universities (Abbas & Faisal, et al., 2024).

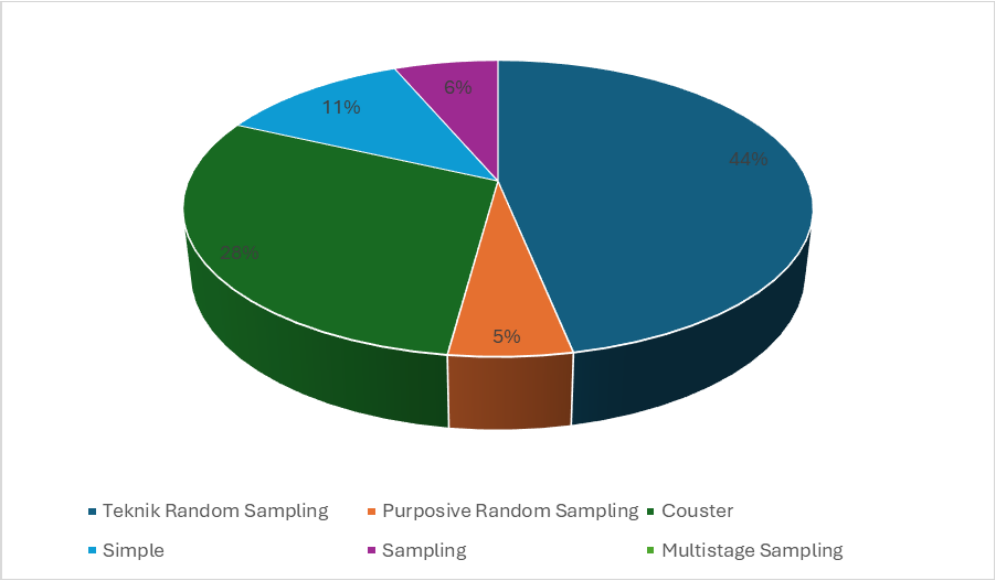


Fig. 2: Sampling in conducting research

The researcher deduces from the aforementioned diagram that 44% of studies utilising quasi-experimental designs in Pakistani educational research implemented the random sampling technique. Purposeful random sampling was the least popular method, used in only 5% of cases. Eleven percent were obtained through simple random sampling, six percent through systematic sampling, and six percent through multistage sampling. Cluster sampling, a method that is often suitable for school-based research in Pakistan, where students are divided into classes or sections, was used in 28% of the studies. The variety of these sampling methods shows how flexible Pakistani researchers are when it comes to picking methods that work for their goals, the problems with the education system, and the realities of classrooms.

The choice of a quasi-experimental design was suitable given Pakistan's organised classroom setting and the logistical difficulties of fully randomising participants across schools. This method allowed for a comparison of pre-test and post-test results by considering baseline differences between groups while maintaining ecological validity (Cook & Campbell, 1979; Shadish, Cook, & Campbell, 2002). When used in a planned way, Technology-Enhanced Learning (TEL) can be a good way to teach Pakistani high school students how to think critically, as shown by the experimental group's steady progress.

It is still important to be aware of some limitations, though. The eight-week intervention period may not accurately reflect TEL's enduring impact on the advancement of critical thinking skills. Additionally, since the study focused solely on one urban school, its findings are not generalisable to rural or underfunded institutions with distinct student demographics and varying levels of technological access. Future research in Pakistan could address these gaps by utilising longitudinal designs, expanding the participant pool to encompass schools from diverse regions, and evaluating the effectiveness of TEL components such as gamification (e.g., Wordwall, Kahoot), adaptive learning platforms, or virtual simulations.

All things considered, the results lend credence to the mounting body of research supporting TEL's inclusion in Pakistan's secondary

education system. TEL provides a potent method for cultivating digital literacy, problem-solving, and critical thinking abilities necessary for succeeding in the twenty-first century by fusing interactive, multimedia-rich instruction with active learning techniques.

Conclusion

The study's findings unequivocally show that Technology-Enhanced Learning (TEL) can be a successful teaching strategy for raising Pakistani secondary school students' critical thinking abilities. Students in the experimental group, who received TEL-integrated instruction (such as interactive digital lessons, subject-specific educational apps, and collaborative online activities), showed noticeably higher gains in post-test performance than their peers in the control group, who were taught using conventional, lecture-based methods. The cognitive domains of analysis, evaluation, and synthesis—all of which are essential to Facione's (2015) conceptualization of critical thinking—showed the most improvement. The results imply that TEL can offer Pakistani students worthwhile chances for active, reflective, and inquiry-driven learning experiences when used in conjunction with good pedagogical practices.

There were a number of things that made the TEL intervention work in Pakistani schools. Combining interactive multimedia, simulation-based problem-solving, and collaborative online platforms created a dynamic and engaging learning environment that encouraged deeper cognitive engagement. Second, the immediate feedback and flexibility of digital tools like online tests, adaptive learning programs, and gamified activities probably helped students think more clearly and make better choices. These tools encouraged iterative development and metacognitive awareness. Finally, the intervention was based on constructivist learning design, which puts a lot of emphasis on applying what you've learnt in real life, giving students more freedom, and solving real-world problems. All of these things are very important for helping students in Pakistan develop higher-order thinking skills.

From a methodological standpoint, evaluating TEL's impact in real-world Pakistani classroom settings was best accomplished by using a quasi-experimental design. Although the degree of causal inference is limited by the lack of full randomization, the study's validity was enhanced by employing a pre-test–post-test nonequivalent control group design to account for baseline differences between groups. In Pakistan, where fully randomized controlled trials are frequently limited by administrative, cultural, and logistical realities, this is in line with the established methodological literature that supports the use of quasi-experimental designs in educational research (Cook & Campbell, 1979; Shadish, Cook, & Campbell, 2002). All things considered, this study contributes to the expanding corpus of empirical data in favor of TEL's incorporation into secondary education in Pakistan. Beyond showing how TEL can improve critical thinking, it emphasizes how crucial it is to prepare students for the intricate, data-driven, and problem-focused demands of the digital age. If TEL is used with thoughtful instructional design and fair access to technology, it can be a transformative tool in promoting the cognitive abilities required for lifelong learning, informed citizenship, and academic success. These implications go beyond specific schools.

Suggestions

The results and conclusions of this study suggest that curriculum planners, policymakers, and educators in Pakistan should systematically incorporate technology-enhanced learning (TEL) strategies into school curricula, especially in subjects like science, math, and social studies where the development of critical thinking is a primary goal. TEL exercises ought to be in line with Pakistan's National Curriculum and intended to foster higher-order thinking skills through interactive simulations, problem-based assignments, collaborative inquiry, and digital content that is pertinent to the local area.

Schools and education departments should fund ongoing professional development programs for teachers that emphasize both pedagogical strategies and technological competencies in order to guarantee successful implementation (Faisal, et al., 2023). Teachers will be better prepared to create tech-rich, student-centered classrooms that foster synthesis, analysis, and evaluation skills. For TEL to last, both city and country schools need reliable internet access, the right devices

(like laptops or tablets), and ongoing technical support. Programs run by the government, like the Digital Pakistan Policy, and partnerships between the public and private sectors that try to close the digital divide should pay special attention to areas that don't have enough access to technology (Faisal, et al., 2023). To enhance the generalisability of findings, subsequent research in Pakistan should implement multi-site studies across various educational contexts, including government, private, and low-cost institutions, while also prolonging the duration of TEL interventions to assess their enduring effects on critical thinking. Researchers should also look into which specific TEL tools, such as collaborative online workspaces, adaptive learning platforms, or gamification tools like Wordwall and Kahoot, work best for students in Pakistan.

Finally, TEL strategies should be changed to fit the different levels of cognitive maturity, learning styles, language skills (English, Urdu, and regional languages), and digital literacy of the students. With these changes, interventions will be fair, inclusive, and culturally appropriate, so that all students, no matter where they come from, can take advantage of TEL's chances to get ready for the demands of 21st-century learning and work.

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