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EFFECT OF E- LEARNING IN DEVELOPING HIGHER ORDER THINKING OF SCIENCE STUDENTS AT SECONDARY LEVEL

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Abstract
This research examined the impact of technology on science students in Punjab, Pakistan's secondary schools, focusing on its role in fostering the growth of higher-order thinking abilities (HOTS). Based on Bloom's Taxonomy and Dale's Cone of Experience, the study contrasted the performance of students in conventional versus technology-enhanced classrooms in the areas of analysis, synthesis, and assessment. Two hundred ninth graders from four different public schools were surveyed using a quantitative causal-comparative methodology. Of them, 100 were tech users and 100 were not. To assess pupils' cognitive abilities, researcher used a researcher- created THOT that had been verified by specialists in the field and was in line with the national curriculum. In terms of HOTS, results showed that technology users scored much higher than non-users, particularly in the areas of synthesis and assessment. Girls also outperformed boys, indicating a gender gap. Subject-by-subject research revealed that technology users made much greater progress in chemistry and physics. In line with worldwide data on the significance of e- learning in promoting 21st-century abilities, these results confirm that digital tools, when well incorporated, may improve creative and critical thinking. The research indicates that for Pakistani students to be prepared for jobs in today's knowledge economy, schools must implement more tech-rich learning environments.
Keywords: *Higher-order thinking skills, Bloom's Taxonomy, Dale's Cone of Experience, technology integration, secondary science education, e-learning, Pakistan.*

1. Introduction

An important result of good education is the development of students' higher-order thinking skills (HOTS), which allow them to think critically and participate in more in-depth intellectual pursuits rather than relying only on memory and rote learning (Al-Ghadouni, 2021). In contrast to lower-order abilities like remembering, comprehending, and applying information (Asiri, 2024), HOTS in Bloom's Taxonomy encompass cognitive processes like analyzing, evaluating, and producing, which need complicated reasoning and intellectual objectivity (Jamshed et al., 2024). Success in academic and real-world situations requires students to be able to think critically, solve problems, and make decisions based on evidence (Hamoud et al., 2025).

Fostering HOTS is especially important in the field of scientific education (Hunt et al., 2015). In addition to memorizing information, laws, and theories, students of science learn to apply what they have learned in novel situations via activities including reasoning, problem-solving, and experimenting (Alghamdi, 2024). Using HOTS efficiently in scientific classes helps students develop their cognitive abilities and encourages them to continue learning throughout their lives by improving their ability to explain events, make educated judgments, and solve issues creatively (Massri, 2018). Teachers often overlook the potential of average or lower-achieving students when assigning activities that need higher-order thinking, according to studies (Tang, 2025). This view restricts the potential for students' cognitive growth in scientific classes and impedes the widespread adoption of HOTS (Sun et al., 2024).

New chances for students to develop higher-order thinking have emerged as a result of the integration of technology into education, especially via e-learning (Alfaisal, 2025). According to Dahal (2023), Kenny (2020), and Pishchukhina and Watson (2021), digital platforms like Moodle and Google Apps offer interactive tools like forums, quizzes, collaborative projects, and

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multimedia resources. These tools can improve problem-solving, critical analysis, and creativity. Facts show that online learning encourages participation via activities that promote HOTS, including scenario-based learning, debate, brainstorming, and role-playing (Cranton, 2016; Heron & Palfreyman, 2021). Additionally, technology-assisted learning settings help students visualize complicated ideas, work together to investigate a problem, and overcome obstacles to participation, all of which promote active learning in scientific classes (Piaw et al., 2025).

Projects like the E-learn Punjab Program seek to equip secondary school students in Pakistan with digital tools that encourage inquiry-based learning and higher-order thinking, in keeping with educational reforms that continue to highlight the use of information technology in classrooms (Siddique & Alshenqeeti, 2020). Unfortunately, there has been a lack of study on the efficacy of these programs, especially when it comes to scientific teaching at the secondary level (Yaniawati, 2023). Given the importance of HOTS in equipping students to solve real-world scientific problems and make significant contributions to the knowledge economy, it is crucial to test whether technology-enhanced classrooms promote these skills more so than conventional classrooms (Althewini, 2023).

Research consistently shows a strong link between active, hands-on learning and the development of higher-order thinking skills (HOTS) in science classrooms. This study draws on Bloom's Taxonomy, Dale's Cone of Experience, and contemporary educational technology research to explain how e-learning fosters advanced cognitive engagement. Dale's Cone of Experience (1969) emphasizes that learners remember more when actively involved rather than passively receiving information. In science, where many processes (e.g., cell division, chemical bonding, nuclear fission) cannot be directly observed, technology-based models and simulations bridge the gap between theory and practice. Interactive tools, visualizations, and simulations allow students to analyze, synthesize, and evaluate concepts in meaningful, applied contexts. Educational technology enhances teaching quality by providing systematic methods for developing critical, creative, and problem-solving skills (OECD, 2015; Bransford et al., 2000). Technology use supports self-directed learning, collaboration, and exploratory activities (Knolzek & Christensen, 2007; Patokorpi, 2007). Brookhart (2010) noted that HOTS involve making connections, applying knowledge, and fostering metacognition, while Richland & Begolli (2016) highlight classroom flexibility that allows students to explore multiple solutions and justify them with evidence. Bloom's Taxonomy (1956) categorizes analysis, synthesis, and evaluation as higher-order skills, guiding teachers to design lessons and assessments that progress from memorization to complex reasoning (Stanny, 2016). Activities that promote assessment and synthesis improve academic performance and creativity (Rajendran & Idris, 2008) and are essential for success in today's knowledge-based society (Chinedu et al., 2015). The current digital era shifts the focus from mere technology access to purposeful integration that deepens thinking (McKeachie & Svinicki, 2006). Strategies such as fostering critical reflection (Ritchhart, 2002) and guiding evaluative judgment (Perkins et al., 1993) prepare students for real-world problem-solving. Computer-assisted simulations, digital models, and online collaboration directly align with Bloom's cognitive framework and Dale's experiential learning theory, equipping learners with analytical, synthetic, and evaluative skills for academic and lifelong success. Founded on these theoretical frameworks, this research compares technology users and non-users in Pakistani secondary science classes in order to gauge the growth of higher-order thinking abilities. The study's aim is to ascertain the average HOTS level among science majors, compare the performance of students in physics and chemistry who use and do not use technology; and examine the differences between the two groups at different HOTS levels, namely analysis, synthesis, and evaluation. It also aims to address these factors in order to inform educational policy and instructional methods in Pakistan by providing evidence-based insights into the impact of e-learning on improving students' cognitive abilities. The objectives of the study are:

i. To determine the level of higher order thinking of secondary science school students.
ii. To determine the effect of E-learning in developing higher order thinking of science students at secondary level

Research Questions of the study are:

i. To what extent do technology-user and non-user secondary science students (E-learn Punjab program), as well as male and female students, differ in their effectiveness in developing higher-order thinking skills?
ii. How do technology-user and non-user secondary science students differ in their effectiveness across subjects (chemistry and physics) and higher-order thinking skill levels (analysis, synthesis, and evaluation)?

Research hypothesis of the study are:

H1: There is no significant mean difference in achievement scores on the test of higher-order thinking (THOT) between technology users and non-users, and between male and female secondary school science students.

H2: There is no significant mean difference in achievement scores on the test of higher-order thinking (THOT) between technology users and non-users across subjects (chemistry and physics) and cognitive skill levels (analysis, synthesis, and evaluation).

2. Literature Review

Higher-order thinking skills refer to cognitive processes that require learners to go beyond simple recall of facts, engaging instead in problem-solving, logical reasoning, decision-making, and drawing informed conclusions (Schulz & FitzPatrick, 2016). They encourage learners to actively process, evaluate, and apply information in novel situations, thereby fostering intellectual independence and deeper learning outcomes. The concept of HOTS originates from Bloom's Taxonomy (1956), later revised by Anderson and Krathwohl (2001), which categorizes cognitive processes into six levels. The lower three levels knowledge, comprehension, and application are generally classified as lower-order thinking skills (LOTS), focusing primarily on rote memorization and straightforward application. In contrast, the upper three levels analysis, synthesis (later reframed as "creating"), and evaluation constitute HOTS, requiring critical reflection, creativity, and judgment. As Saifer (2018) notes, these skills involve complex cognitive manipulation that equips learners to adapt knowledge to diverse contexts, making HOTS essential for academic achievement and lifelong learning.

Zohar and Dori (2003) argued that integrating HOTS within science classrooms enhances students' reasoning and problem-solving abilities, while Gillies et al. (2014) highlighted their role in promoting collaborative inquiry and critical discussion. However, despite their importance, studies reveal a persistent gap in classroom practices, as many teachers reserve tasks demanding HOTS for high-achieving students, leaving others with routine or mechanical tasks (Zohar & Vaaknin, 2001). This underlines the necessity of embedding HOTS into teaching practices for all learners, particularly at the secondary level, where scientific reasoning and

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problem-solving are critical for both academic and personal development.
Clark and Mayer (2016) argued that effective e-learning combine's multimedia tools and instructional design principles to enhance comprehension and critical engagement. Research by Ganapathy et al. (2017) and Suchyadi et al. (2021) demonstrates that e-learning platforms allow students to observe, analyze, and synthesize information through interactive graphics, animations, and videos, thereby stimulating HOTS. However In this study, *technology users* are conceptualized as public secondary schools in Pakistan that are part of the *E-Learn Punjab Program*, which integrates technology into classrooms using tools such as LED displays and tablets. This initiative reflects the government's efforts to modernize instructional practices by embedding e-learning resources into science education, aiming to enhance critical inquiry, engagement, and cognitive development. Research by Cunningham et al. (1993) and more recently by Aziz and Rawian (2022) suggests that technology-integrated classrooms not only increase motivation but also promote teamwork, reasoning, and problem-solving skills. Thus, technology users are positioned to cultivate higher-order thinking through structured access to digital resources and interactive pedagogical practices.
Conversely, *non-technology users* in the current study refer to schools that continue to rely on traditional, teacher-centered methods without integrating digital tools into their classrooms. These schools emphasize lecture-based teaching and textbook-driven instruction, where student engagement largely revolves around note-taking and rote memorization. While such methods may reinforce basic comprehension, research indicates they are less effective in stimulating critical reasoning, analytical problem-solving, and creative application key dimensions of HOTS (Forehand, 2010; Yahya, Toukal, & Osman, 2012). Consequently, non-technology user schools often lag behind in cultivating students' higher-order cognitive skills, especially in science subjects that demand analytical and reflective inquiry.
According to Saido et al. (2025), teaching students to think critically and creatively should be the primary focus of science classes so that they can better handle the problems they will encounter in real life. Kurdish science curricula in Iraqi Kurdistan focus on helping pupils develop their capacity for higher-order thinking. Finding out how well seventh graders can use higher-order thinking abilities was the primary goal of this research. Twenty multiple-choice questions made up the Higher Order Thinking Level Test (HOTLT), which was created using the Bloom Taxonomy of Cognitive Domains. In the Iraqi-Kurdistan area, 418 seventh graders were selected at random to take the exam. In general, the results showed that a large percentage of seventh graders ($n = 278$ or 79.7% of the total) had lower-level thinking abilities. Male pupils outnumbered female students at the lower level. Nonetheless, gender did not significantly correlate with pupils' levels of higher-order thinking abilities ($p > 0.05$). According to the study's findings, almost all students might benefit from honing their higher-order thinking abilities, particularly the ability to synthesize and evaluate information, which are crucial for fostering scientific creativity.
New Zealand is one of several nations that have included the development of higher-order thinking abilities in its national curriculum objectives, as stated by Hunt et.al (2015). This shift is driven by global trends in technology, social and economic development. There is a growing consensus among educators and policymakers in this nation and elsewhere that kids may acquire

these competencies via the use of digital technology. The SOLO taxonomy, developed by Biggs and Collis in 1982, is a widely used method for determining higher-order thinking. Both the questions and the assignments themselves may be classified according to this taxonomy, which indicates the level of complexity in student replies. With the use of SOLO levels, which differentiate between superficial and deep thinking, educators want to help their pupils develop the latter.

As a result of globalization, students' learning goals have shifted significantly, and educators in the modern day must find ways to captivate students using a variety of approaches. Mehmood et al. (2019) studied a public school in Punjab province to see how mixed-ability classes affected the students' ability to think critically and creatively about biology in secondary school. Over eight weeks, the researcher covered the material from the biology textbook for tenth grade using a combination of KWLH charts, hands-on activities, multimedia integration, and cooperative learning. The only design used in this experimental study was the posttest. Fifty multiple-choice questions tested the HOTS of the biology class. When comparing the two groups after the intervention, the experimental group showed more improvement in the biology students' HOTS. The combined instructional tactics not only helped high achievers improve their HOTS but also benefited poor achievers, as indicated by the t-test findings.

Aiming to cultivate HOTS in students is a significant component of 21st-century skills, and educators are rethinking their pedagogical practices to attract the multi-faceted digital learners of today (Scott, 2015). Students' learning abilities may be enhanced by using integrated teaching tactics, according to Creemers (2005) and Eison (2010). These strategies focus on developing students' higher-order thinking capabilities (hence referred to as HOTS). Their capacity for higher-order thinking was significantly improved as a result of the consistent use of mixed-methods pedagogy, which encouraged students to participate in class actively. Both low- and high-achieving biology students' HOTS were significantly impacted by combined teaching tactics, according to Ramos and Morales (2016), who urged researchers to reproduce their findings in other settings. Another research by Zohar and Dori (2003) indicated that when using mixed teaching tactics, low achievers made more progress than high achievers. The National Curriculum for Biology (2006) in Pakistan aims to encourage students to think scientifically and in a higher order through the use of a variety of teaching strategies. This is because it is a challenge for both developed and developing nations to focus on students' thinking skills. Pupils need to possess both lower-level and higher-level thinking abilities in order to excel in today's demanding educational environment. Students' cognitive abilities are a key component of 21st-century skill sets; improved cognition is associated with higher-order thinking skills, which in turn improve students' learning capacity, speed, and capacity to absorb and accommodate new information. The HOTS framework has its origins in Bloom's taxonomy and has been discussed in many settings over the years. It encompasses content thinking, critical and creative elements, problem-solving, creativity formulation, and successful communication. In order to foster higher-order thinking abilities in the classroom, students need to know and understand the material in order to apply it. In order to promote higher-order thinking skills (HOTS) in the classroom, students must be able to understand and apply course material in ways that promote self-regulation, self-awareness, self-control, and self-correction. Students can describe ideas better, make predictions, use their inferences to assess their concepts, and employ their perspectives when they engage in higher-order thinking.

3. Research Methodology

The present study was conducted within the paradigm of positivism, which emphasizes objectivity, measurement, and the testing of hypotheses through empirical evidence. Consistent with this paradigm, the study adopted a quantitative research approach and was descriptive in nature, employing a causal-comparative research design. This design was appropriate as it allowed the researcher to examine differences in higher-order thinking skills (HOTS) between groups of students exposed to technology-integrated classrooms and those in traditional classrooms without manipulating the learning environment. The population of the study comprised secondary-level science students from schools associated with the Punjab E-Learn program and comparable nearby schools not using the program. According to the initial rollout of the Punjab E-Learn program, eight public schools were identified, including:

- Government Model High School, Khanewal
- Government Girls High School, Gulshan-e-Ravi, Lahore
- Government Boys Central Model School, Lahore
- Government Girls Higher Secondary School No.1, Attock
- Government Sadiq High School, Bahawalpur
- Government High School, Joharabad
- Daanish School for Boys, Rajanpur
- Government Girls High School No. 2, Gujranwala

From this list, and keeping in view the study objectives, four schools were purposively selected. Two schools using technology under the E-Learn Punjab program (Government Girls High School and Government Central Model High School) were included, along with two non-technology user schools (Government Model Girls High School and Pilot Secondary High School for Boys). The final sample consisted of 200 students (boys and girls), with 100 technology users and 100 non-technology users. Data were collected using the Test of Higher Order Thinking (THOT) questionnaire, which was developed by the researcher in alignment with Bloom's Taxonomy. The test was specifically designed for science subjects, focusing on chemistry and physics, ensuring inclusivity for students from both computer science and biology groups. The content of the test was aligned with the Grade 9 curriculum, and careful consideration was given to ensure that students had already covered the relevant content by the time of administration. The THOT instrument was structured around problem-based complex situations to assess students' skills in analysis, synthesis, and evaluation. An initial pool of 48 items was developed, from which two final tests were constructed, each comprising 18 items. Additionally, for each content area and cognitive level, two extra items were prepared, with the best-performing three selected through expert review. Students were provided an average of two hours to complete the test, with additional time allowed for those requiring it. To ensure reliability and objectivity, a rubric was developed to evaluate responses based on both accuracy and comprehensiveness. A two-way chart was also constructed to determine content-specific weightings for the test items, ensuring a balanced representation of both subject matter and cognitive levels within Bloom's higher-order domains.

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Table 1 Content-Specific Weightings for the Test Items

Class	Content/ Unit	Cognitive Dimensions			No. Of Items By Content Area
		ANALYSIS	SYNTHESIS	EVALUATION	
9th Chemistry		3	3	3	9
9th Physics		3	3	3	9
		6	6	6	18

The Test of Higher Order Thinking (THOT) was validated by a panel of subject and assessment experts to ensure alignment with Bloom's higher-order thinking levels (analysis, synthesis, evaluation), the Grade 9 science curriculum, and clear, unbiased language. The scoring rubric was reviewed for fairness, comprehensiveness, and appropriate emphasis on reasoning depth. Inter-rater reliability was established by having four experts independently score responses from a pilot group of 10 non-sample students. Fleiss' Kappa yielded a coefficient of 0.75 or higher, indicating strong agreement and confirming scoring consistency. The study targeted four secondary schools: two technology-user schools under the E-Learn Punjab program and two non-user schools. The THOT questionnaire was administered to Grade 9 science students after initial pilot testing confirmed the instrument's clarity and feasibility. Prior to data collection, formal permission was obtained from the heads of the participating institutions. Students were informed that the test was not an assessment affecting their academic results but a research activity to evaluate learning approaches. Clear instructions were provided, emphasizing the importance of independent work. During administration, students were asked to carefully read each problem-based situation and respond logically using their analytical, synthetic, and evaluative skills. Teachers and the researcher ensured that students worked individually without assistance and that all students completed the test. Additional time was allowed where necessary to reduce test anxiety and ensure comprehensive responses.

4. Data Analysis

For statistical analysis data was coded, summarized, cleaned and checked for missing item. No missing item was found, normality was also ensured by skewness and kurtosis value. Standard deviation and means were calculated through descriptive statistics. Another statistics of t-test was used to compare the differences between technology users and non-users.

i. Higher-Order Thinking Skills by Technology Use and Gender

Table 2 Independent Samples t-test Results for Total Achievement Scores by Technology Use and Gender

Variable	Group	N	Mean	Std. Deviation	T	Df	P
Technology Use	**Tech Users**	100	20.86	6.64	4.354	193.439	.000
	Non-Users	100	16.41	7.75			
Gender	**Girls**	100	19.96	5.18	2.510	156.586	.013
	Boys	100	17.32	9.15			

The findings of this study reveal statistically significant differences in higher-order thinking skills (HOTs) based on both technology integration and gender. The results show that technology-user students (M = 20.86, SD = 6.64) significantly outperformed non-users (M = 16.41, SD = 7.75) in total achievement scores on the Test of Higher-Order Thinking (THOT), $t(193.439) = 4.354$, $p < .001$. This supports the premise of the E-learn Punjab program, which is grounded in the idea that technology-enhanced learning environments promote active engagement, problem solving, and application of knowledge core aspects of HOTs (Bloom, 1956; Anderson & Krathwohl, 2001). These findings align with constructivist learning theories (Vygotsky, 1978) and cognitive development perspectives, which emphasize that interactive and technology-rich environments provide scaffolding that enables learners to engage in deeper cognitive processes such as analysis, synthesis, and evaluation. Consistent with prior research (Schulz & FitzPatrick, 2016; Saadé et al., 2012), the study indicates that digital learning tools support collaborative problem solving, immediate feedback, and self-paced exploration, which in turn enhance higher-order cognitive performance.

Female students (M = 19.96, SD = 5.18) scored significantly higher than male students (M = 17.32, SD = 9.15), $t\ (156.586) = 2.510$, $p = .013$. This is consistent with studies such as Hyde and Linn (2006) and Else-Quest et al. (2010), which have reported that female students often exhibit stronger academic performance in structured learning environments, particularly when assessment tasks require critical reasoning and comprehension. One possible explanation, supported by social cognitive theory (Bandura, 1986), is that female students in the sampled schools may have demonstrated greater motivation, discipline, and persistence traits that positively influence HOTs performance. The findings reinforce the conceptual linkage between Bloom's higher cognitive domains and the benefits of technology-enhanced learning environments. Technology's capacity to provide interactive, multimodal, and context-based learning aligns with the upper levels of Bloom's Taxonomy analysis, synthesis, and evaluation while also validating Vygotsky's emphasis on mediated learning experiences through digital tools. In addition, the gender-related differences invite further consideration of motivational and socio-cultural factors in cognitive skill development, highlighting the need to tailor technology integration strategies that address the needs and learning styles of both boys and girls.

ii. Higher-Order Thinking Skills across Subjects and Cognitive Levels by Technology Use

Table 3 Comparison of Technology Users and Non-Users for Development of Higher-Order Thinking Skills

Domain / Subject	Group	N	Mean	Std. Dev.	T	Df	P
Chemistry	**Tech Users**	100	10.0067	4.06531	3.559	197.509	.000
	Non-Users	100	7.9075	4.27343			
Physics	**Tech Users**	100	10.9850	3.14257	4.562	178.442	.000
	Non-Users	100	8.5063	4.43295			
Analysis Level	**Tech Users**	100	4.8800	2.09752	1.295	198	.197
	Non-Users	100	4.4500	2.57560			
Synthesis Level	**Tech Users**	100	4.0850	1.64233	6.936	197.962	.000
	Non-Users	100	2.4850	1.61973			
Evaluation Level	**Tech Users**	100	6.0500	1.75162	3.71	183.351	.000

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				0
Non-Users	100	4.9650	2.34224	

The results presented in Table 2 indicate notable differences between technology users and non-users in the development of higher-order thinking skills (HOTS) across subjects (Chemistry, Physics) and cognitive skill levels (Analysis, Synthesis, Evaluation).

In Chemistry, technology users ($M = 10.01$, $SD = 4.07$) scored significantly higher than non-users ($M = 7.91$, $SD = 4.27$), $t(197.509) = 3.559$, $p < .001$. Similarly, in Physics, technology users ($M = 10.99$, $SD = 3.14$) outperformed non-users ($M = 8.51$, $SD = 4.43$), $t\ (178.442) = 4.562$, $p < .001$. These findings align with the constructivist perspective of learning (Piaget, 1972; Vygotsky, 1978), which posits that interactive and technology-supported environments foster deeper conceptual understanding by enabling students to actively engage with content. The use of E-Learn Punjab's technology-integrated resources likely provided students with visual, interactive, and problem-based materials that support cognitive engagement beyond rote memorization. This supports previous studies (Higgins, Xiao, & Katsipataki, 2012; Tamim et al., 2011) showing that technology integration enhances science learning outcomes by promoting active inquiry and visual representation of abstract concepts.

At the Analysis level, no significant difference was found between technology users ($M = 4.88$) and non-users ($M = 4.45$), $t(198) = 1.295$, $p = .197$. This suggests that analytical reasoning skills such as identifying patterns, dissecting concepts, and recognizing cause–effect relationships may not be substantially influenced by technology integration alone, and might depend more on instructional strategy, questioning techniques, and teacher scaffolding (Anderson & Krathwohl, 2001).

However, Synthesis level results show a substantial advantage for technology users ($M = 4.09$) over non-users ($M = 2.49$), $t(197.962) = 6.936$, $p < .001$. This aligns with the idea that technology-rich environments provide opportunities for students to combine multiple concepts and create new solutions through simulation tools, collaborative projects, and multimedia resources (Mishra & Koehler, 2006).

Similarly, in Evaluation level tasks, technology users ($M = 6.05$) scored significantly higher than non-users ($M = 4.97$), $t(183.351) = 3.710$, $p < .001$. This supports Bloom's taxonomy framework, where evaluation represents a higher cognitive demand involving judgment, critical appraisal, and decision-making. Interactive learning technologies facilitate such processes by allowing learners to test hypotheses, compare alternatives, and justify reasoning skills essential for evaluation (King, Goodson, & Rohani, 2013).

Overall, these findings reinforce the theoretical position that higher-order cognitive skills can be significantly enhanced through technology integration, particularly in the domains of synthesis and evaluation, while analysis skills may require complementary pedagogical interventions. The results are consistent with empirical studies (Cheung & Slavin, 2013; Voogt et al., 2015) that highlight the role of technology in facilitating collaborative learning, real-time feedback, and visualization of scientific concepts, all of which contribute to deeper learning and HOTS development.

5. Discussion

This research found that secondary science students in Pakistan might greatly benefit from using technology to enhance their higher-order thinking abilities (HOTS). Results indicated that students' higher-order thinking abilities ranged from 2.13 to 35.50, with a mean score of 18.51 ($SD = 7.27$). This large variation shows that students' abilities to analyse, synthesise, and evaluate at the three levels at the top of Bloom's taxonomy vary widely (Bloom, 1956; Krathwohl, 2002). This diversity is attributed, in Bloom's model, to variations in pedagogy, classroom settings, and availability of relevant technology. These results align with those of Perkins et al. (1993), who contended that students' cognitive development is boosted when they actively participate in activities requiring problem-solving and critical thinking skills.

The mean difference between those who utilise technology and those who do not was statistically significant. According to Dale's Cone of Experience (1969), which highlighted the efficacy of active, experiencing, and visual learning, technology users fared better than non-users (M = 20.85 vs. M = 16.41). To better connect with abstract scientific topics, students in E-learn Punjab schools had access to digital simulations, animations, and interactive materials that provided artificial and sensory experiences. These results are in line with those of Bransford et al. (2000) and Knezek & Christensen (2007), who found that the use of technology improves learning outcomes by encouraging creative and critical thinking.

Girls achieved higher mean scores (M = 19.95) than boys (M = 17.31), revealing a statistically significant difference between the sexes in the present investigation. The results imply that female students could gain more from organised and collaborative online learning settings, even if the effect size were tiny. This aligns with what Richland and Begolli (2016) found: students are more engaged in class when teachers provide opportunities to express creativity and make connections between what they already know and what they are learning. Since cultural and motivational variables in Pakistan could impact performance disparities, these findings also call attention to the need for more gender-focused research (Giancarlo-Gittens, 2009; Moon, 2008).

Technology users outperformed non-users in chemistry and physics, according to the subject-specific data. This supports Patokorpi's (2007) assertion that technology enhances the realism of learning experiences by allowing students to picture and recreate micro-level events, such as atomic bonding and cell division, which would otherwise be impossible to see. According to Dale's paradigm, students go from simple memorisation to more complex analysis and assessment via these types of virtual experiences. Songkram (2015) also found that students' capacity to work together, use both tacit and explicit knowledge, and make sense of abstract ideas is improved by using digital tools. Results from analyses spanning all levels of Bloom's taxonomy were inconsistent. Those who used technology and those who did not showed little difference. Technology users showed a big and statistically significant advantage, which may indicate that multimedia apps, collaborative tools, and simulations greatly facilitate the development of novel solutions to problems and new bodies of knowledge. The significance of group-based and technology-supported activities in fostering creativity and synthesis was emphasised by Rajendran and Idris (2008), reflecting their sentiments. People who used technology also did far better than those who did not. This result is in line with the work of Brookhart (2010) and Ritchhart (2002), who emphasised the importance of reflective practices and technology-supported discourse in developing students' ability to think critically and make reasoned conclusions. The results support Dale's Cone of Experience theory by showing how visual and interactive technology connects students' real-world experiences with theoretical scientific ideas. The findings also align with Bloom's Taxonomy, suggesting that students may excel in analysis in either a conventional or tech-rich setting. However, e-learning interventions are particularly effective for higher-level skills like synthesis and assessment.

This research validates the findings of Suchyadi et al. (2021) and Ganapathy et al. (2017), which show that online learning resources improve HOTS by facilitating group work, discussion, and the resolution of problems. Nevertheless, Zohar & Vaaknin (2001) found no difference in the degree of analysis, which is in line with our findings. They pointed out that professors tend to give more advanced assignments to students who excel in class, which might prevent these students from reaching their full analytical capacity when using technology. The significance of increasing the integration of technology in secondary schools in Pakistan is shown by these findings. Additional teacher training is necessary to ensure that analytical skills are equitably fostered, even though the E-learn Punjab program has the potential to improve synthesis and assessment abilities. For HOTS to influence the long run, they need to be consistently integrated into the curriculum, pedagogy, and evaluation.

6. Conclusion

This study found that secondary science students using the Punjab E-learn program significantly outperformed non-users in developing higher-order thinking skills (HOTS), especially in synthesis and evaluation, supporting Bloom's Taxonomy and Dale's Cone of Experience. Technology-based tools such as simulations and interactive content transformed abstract concepts into meaningful learning, with female students generally outperforming male students. These results affirm that technology is a key driver of deeper cognitive growth, shifting teachers' roles toward facilitation and inquiry-based learning. The government should expand the E-learn program across rural and urban schools, ensure equitable access to digital resources, and provide continuous teacher training focused on designing HOTS-oriented tasks. Curriculum reforms should embed 21st-century skills, with robust monitoring systems to evaluate program impact. Addressing gender disparities and reducing the digital divide are essential for inclusive implementation. The study's scope was limited to four schools in Punjab, focused only on chemistry and physics, and measured short-term outcomes. Factors such as socioeconomic background and resource availability may also have influenced results. Long-term and cross-disciplinary studies with larger, more diverse samples are needed. Mixed-method approaches, teacher practice investigations, and equity-focused analyses will provide deeper insights into technology's role in enhancing HOTS.

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