DOI(Journal): 10.31703/gssr
DOI(Volume): 10.31703/gssr.2025(X)
DOI(Issue): 10.31703/gssr.2025(X.II)

p-ISSN: 2520-0348

e-ISSN: 2616-793X

GSSR

GLOBAL SOCIAL SCIENCES REVIEW

HEC-RECOGNIZED CATEGORY-Y

Volum X, ISSUE II SPRING (JUNE-2025)

Double-blind Peer-review Journal
www.gssrjournal.com

Humanity Publications(HumaPub)
www.humapub.com
Doi: https://dx.doi.org/10.31703

Article Title

The Impact of Digital Technologies on Student Engagement in Science Teaching at the Higher Secondary Level

Abstract

This study investigates the role of digital technologies in enhancing student engagement in science education at the higher secondary level, focusing on institutions in Multan. Using a quantitative research design, data were collected from 203 students through a structured questionnaire based on a 5-point Likert scale. The results indicate that digital tools such as simulations, virtual labs, and multimedia resources significantly improve students' motivation, participation, and conceptual understanding. Female students demonstrated slightly higher engagement levels compared to males. A strong positive correlation was found between enabling factors and engagement (r = 0.60), while challenges showed a negative correlation (r = 0.42). The findings underscore the need for strategic investments in digital infrastructure, teacher training, and curriculum-aligned content. This research contributes to developing effective digital teaching strategies and provides actionable insights for educators and policymakers aiming to enhance science education through technology integration in secondary schools.

Keywords: Digital Technology, Student Engagement, Higher Secondary, Science Teaching

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Pages: 55-65
DOI:10.31703/gssr.2025(X-II).05
DOI link: https://dx.doi.org/10.31703/gssr.2025(X-II).05
Article link: http://www.gssrjournal.com/article/A-b-c
Full-text Link: https://gssrjournal.com/fulltext/
Pdf link: https://www.gssrjournal.com/jadmin/Auther/31rvIolA2.pdf

Global Social Sciences Review

p-ISSN: 2520-0348 **e-ISSN:** 2616-793x
DOI(journal):10.31703/gssr
Volume: X (2025)
DOI (volume):10.31703/gssr.2025(X)
Issue: II Spring (June 2025)
DOI(Issue):10.31703/gssr.2024(X-I)

Home Page
www.gssrjournal.com

Volume: IX (2024)
https://www.gssrjournal.com/Current-issue

Issue: II-Spring (June-2025)
https://www.gssrjournal.com/Current-issues/10/2/2025

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Doi: https://dx.doi.org/10.31703

Citing this Article

05	The Impact of Digital Technologies on Student Engagement in Science Teaching at the Higher Secondary Level		
Authors	M. Saeed Shakir Shanza Marium Aqsa Majeed	DOI	10.31703/gssr.2025(X-II).05
		Pages	55-65
		Year	2025
		Volume	X
		Issue	II

Referencing & Citing Styles	
APA	Shakir, M. S., Marium, S., & Majeed, A. (2025). The Impact of Digital Technologies on Student Engagement in Science Teaching at the Higher Secondary Level. *Global Social Sciences Review*, *X*(II), 55-65. https://doi.org/10.31703/gssr.2025(X-II).05
CHICAGO	Shakir, M. Saeed, Shanza Marium, and Aqsa Majeed. 2025. "The Impact of Digital Technologies on Student Engagement in Science Teaching at the Higher Secondary Level." *Global Social Sciences Review* X (II):55-65. doi: 10.31703/gssr.2025(X-II).05.
HARVARD	SHAKIR, M. S., MARIUM, S. & MAJEED, A. 2025. The Impact of Digital Technologies on Student Engagement in Science Teaching at the Higher Secondary Level. *Global Social Sciences Review*, X, 55-65.
MHRA	Shakir, M. Saeed, Shanza Marium, and Aqsa Majeed. 2025. 'The Impact of Digital Technologies on Student Engagement in Science Teaching at the Higher Secondary Level', *Global Social Sciences Review*, X: 55-65.
MLA	Shakir, M. Saeed, Shanza Marium, and Aqsa Majeed. "The Impact of Digital Technologies on Student Engagement in Science Teaching at the Higher Secondary Level." *Global Social Sciences Review* X.II (2025): 55-65. Print.
OXFORD	Shakir, M. Saeed, Marium, Shanza, and Majeed, Aqsa (2025), 'The Impact of Digital Technologies on Student Engagement in Science Teaching at the Higher Secondary Level', *Global Social Sciences Review*, X (II), 55-65.
TURABIAN	Shakir, M. Saeed, Shanza Marium, and Aqsa Majeed. "The Impact of Digital Technologies on Student Engagement in Science Teaching at the Higher Secondary Level." *Global Social Sciences Review* X, no. II (2025): 55-65. https://dx.doi.org/10.31703/gssr.2025(X-II).05.

e-ISSN:2616-793x | Volume: X (2025) | Issue: II-Spring (June-2025) | p-ISSN:2520-0348

Global Social Sciences Review
www.gssrjournal.com
DOI:http://dx.doi.org/10.31703/gssr

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Title

The Impact of Digital Technologies on Student Engagement in Science Teaching at the Higher Secondary Level

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Contents

Abstract

This study investigates the role of digital technologies in enhancing student engagement in science education at the higher secondary level, focusing on institutions in Multan. Using a quantitative research design, data were collected from 203 students through a structured questionnaire based on a 5-point Likert scale. The results indicate that digital tools such as simulations, virtual labs, and multimedia resources significantly improve students' motivation, participation, and conceptual understanding. Female students demonstrated slightly higher engagement levels compared to males. A strong positive correlation was found between enabling factors and engagement (r = 0.60), while challenges showed a negative correlation (r = 0.42). The findings underscore the need for strategic investments in digital infrastructure, teacher training, and curriculum-aligned content. This research contributes to developing effective digital teaching strategies and provides actionable insights for educators and policymakers aiming to enhance science education through technology integration in secondary schools.

Keywords:

Digital Technology, Student Engagement, Higher Secondary, Science Teaching

Introduction

Digital technology includes all electronic tools, systems, devices, and resources that generate, store, or process data. Examples include smartphones, digital cameras, e-readers, scanners, and computer hard drives. However, digital technology extends beyond personal gadgets; it also encompasses innovations such as the Internet, enabling global communication, and blockchain technology, which secures and decentralizes financial systems (Schindler et al., 2017).

Numerous studies indicate that student motivation and engagement improve with instructional technology. Technology enhances student engagement in multiple ways: behaviorally (increased participation in learning activities), emotionally (positive attitudes and interests toward learning), and cognitively (mental investment to comprehend content) (Schindler et al., 2017). Whether integrated during class or used for after-school learning, technology provides students with greater opportunities to interact with instructors, collaborate with peers, and immerse themselves in the learning process. Specific technological tools that enhance student engagement include web-conferencing software, blogs, wikis, social networking sites, and digital games (Alam & Asimiran, 2021).

The Role of Technology in Sustainable Development

The Internet of Things (IoT) has emerged as an efficient and cost-effective tool for enhancing learning experiences and expanding access to quality education (Dreimane & Upenieks, 2022).

Traditional classroom settings often lack the immediacy and engagement that digital tools offer. Digital technology enhances the efficiency of learning methodologies, making education more interactive and accessible. However, its implementation requires careful management, as traditional instructors may perceive digital tools as distractions rather than learning aids (Vakaliuk et al., 2021).

The history of digital technology goes back to the ancient Abacus, which is used for arithmetic calculations. In the 17th century, we introduced a mechanical calculator pointing to the beginning of a computing device. The 20th century witnessed the emergence of an electronic computer that developed the size of the room to the smallest high-speed device used today (Khan et al., 2020).

Research on learning results in higher education is still limited in relation to students' participation and higher education, especially in technology innovation, such as virtual reality (VR) and games. In addition, further studies are required to ensure a fair approach to technology for students in demolished origin or rural areas (Schindler et al., 2017). In addition, research should study the strategy to effectively integrate technology into a higher curriculum in consideration of unique cultural contexts and pedagogy traditions (Alam & Asimiran, 2021).

This study aims to contribute to educational literature by studying the influence of digital technology on students and learning results. In addition, we would like to provide practical information to educational institutions, teachers and politicians in the development of adaptive digital education policies.

One of the common topics in various studies is the importance of teaching teachers and supporting the successful implementation of educational technology. Research emphasizes the balance of educational content and technical tools to maximize learning results (Schindler et al., 2017). All studies emphasize the need for teaching teachers, but they differ in relation to certain types of learning. For example, Alam and Asimiran (2021) emphasize the need to teach teachers related to VR, while Khan et al. (2020) focus on gamed learning experience.

Literature Review

In the rapidly developing digital era, important changes change the educational environment, especially in the interaction of training (bonfield et al., 2020). This change comes from technological achievement and innovative educational management strategies. ICT not only innovated the revolution of information but also changed the approach to education and training (Ahmaddien et al., 2022; Genlott et al., 2019). This study explores the influence of technical innovation and educational management strategies on interaction training in the digital age as a major purpose to increase students' participation.

Students' participation is a decisive factor in determining the success of learning (Schnitzler et al., 2021). In the age of technology, in the age of everyday life, the role of education cannot be ignored (Dainamang et al., 2024; Damopolii & Kurniadi, 2019; IIVARI et al., 2020; Maharani et al., 2024). Online educational platforms, educational applications, and interactive tools create dynamic dynamics that focus on students (Haleem et al., 2022).

Nevertheless, these technical achievements also represent problems in the field of education and management, which must be considered for successful implementation (UR & KOLAD, 2019). This study contributes to the development of appropriate and responsive educational models, ensuring digital education is effective and contributing to students' participation.

Role of Technology in Training

Technology integration has been widely studied in recent years (Huang et al., 2020). ALAM and Asminiran (2021) studied the effects of VR (Virtual Reality), and students studied the effects of participation in male piers and found that VR has greatly improved its interactions to provide an interesting and interactive learning experience. The study also emphasized the need to teach and support teachers when implementing VR technology in class.

In the same way, the gaming method improves students' motivation and participation to make training more interactively and enjoyable (Huang et al., 2020; Raju et al., 2021). Nevertheless, effective learning results require a balance between game elements and educational content.

Zainiyati et al. (2021) examined the classrooms that were reversed in higher education and emphasized how this model could improve the students related to students and work at their own speed. The study showed positive results but emphasized the importance of teacher support and feedback in optimizing learning results. Further studies show that the integration of technical learning strategies such as reverse classes must be accompanied by appropriate training and leadership of teachers (Affida & Zainiyati, 2022).

This study is consistent with a broader literature that emphasizes autonomy, and interaction with colleagues and teachers as major interaction factors (Adiyono et al., 2023b). Studies have shown that student interactions have a significant impact on participation and learning results (Merlin-Knoblich et al., 2019). In addition, technological achievements affect global education during the crisis such as KOSTOPOULOS & KOTSIIANTIS (2022). Digital technology allows students to continue their education remotely by guaranteeing the continuity of the curriculum.

Technology integration in the classroom is more dynamic and dynamic than training by improving students' participation. Using online creators' projectors, computers, and tools, contributes to active participation. In addition to traditional shoe communication, this technology provides more extensive participation through interactive work and digital presentations (bonfield et al., 2020). Digital education also contributes to the sustainability of education by reducing dependence on physical resources (Camilleri & Camilleri, 2017).

Statement of the Problem

Integrating digital technology into education, especially in science education, has changed world education and training. At the highest average level where conceptual understanding and practical application are important, students play an important role in academic success. However, despite the increase in the use of digital tools and resources, there is a lack of clarity on the actual impact of students participating in scientific classes.

Digital technology provides promising opportunities for interactive and innovative teaching methods, but effective integration creates some problems. Problems such as inappropriate teacher preparation, restricted approaches to resources, and various levels students of students' students of students can interfere with a learning experience. In addition, at this level, you need to determine the most effective digital tools and methods to improve the transmission and understanding of scientific content.

Therefore, this study aims to study the effects of digital technology on teaching students science to average, determine major problems and opportunities, and analyze the effects of various digital technologies to improve the learning of science education. The results will contribute to the development of effective digital learning strategies that contribute to the deeper participation of students and the best results in science education.

Research Objectives

1. To examine the impact of digital technologies on student engagement in science teaching at the higher secondary level.
2. To identify challenges and opportunities in integrating digital technologies for improving student engagement in higher secondary-level science education.
3. To analyze the effectiveness of various digital technologies in enhancing the delivery of

science education at the higher secondary level."

Research questions

1. What is the impact of digital technologies on student engagement in science teaching at the higher secondary level?
2. What are the challenges and opportunities in integrating digital technologies for improving student engagement in higher secondary-level science education?
3. What is the effectiveness of various digital technologies in enhancing the delivery of science education at the higher secondary level?

Delimitations

"This study is geographically delimited to the district of Multan, focusing on higher secondary education institutions. Data is collected from Physics students, specifically regarding the use of digital technology."

Methodology:

Research Design

This study employed a quantitative research design to examine the impact of digital technologies on student engagement in science teaching at the higher secondary level. The approach allowed for the collection and analysis of numerical data to draw objective and statistically valid conclusions.

Population and samples

The total population of this study consists of 1,100 students with the highest average level. From this population, we used the appropriate sampling method to select 203 student samples to ensure the presentation and reliability of the results.

Instruments

Self -based questionnaire has been developed as a major data collection tool. Based on variable studies, it consists of 30 operators and five -point cut measures, and consists of measured answers and does not agree with complete consent. The questionnaire was built to evaluate the dependence and independent variables, especially the goals of the research and one independent variable.

Data Collection and Analysis

Technical statistics, including average values, standard deviations, frequency and interest, have been used to summarize data and indicate the general trend of students' answers. ANOVA (distributed analysis) and regression analysis were used to determine the relationship and difference between variables. This logical statistics provided ideas on the effects and effects of digital technology on students' participation.

Ethical consideration

Participants were known about the purpose of research and their participation was voluntary. Anonymous performance and confidentiality of the respondents were strictly supported throughout the study.

Table 1

Demographics

Sr.	Title	Description	Frequency	Percentage
1	Gender	Male	79	38.9%
		Female	124	61.0%
2	Age	15-17	132	64.7%
		18-20	67	33.0%
4	Computer usage of the respondent	None	55	27.0%
		Daily	133	65.5%
		Weekly	9	4.43%
		Monthly	6	2.95%

Table 1 shows the demographic profile of the research respondents, most of which are women (61.0%) compared to men (38.9%). According to age distribution, most participants are 15 to 17 years old (64.7%), which are mainly composed of high school students, and smaller segments are between 18 and 20 years old (33.0%). In terms of computer use, a large portion of the respondents (65.5%) announced the use of computers a day, which represents the majority of digital interactions. Nevertheless, 27.0%of the participants answered that there was no computer, which represents the group's significant digital gap. Small interest includes access to various levels of digital tools using computers every week (4.43%) or monthly (2.95%). These demographic models are important to understand the context of digital technology integrated into science education and can affect the level of interaction and learning results observed in the study.

Table 2

Impact of digital technologies on student engagement

Description	N	Mean	Std. Deviation
Digital technologies make science lessons more interactive and engaging.	203	4.20	0.76
Using digital tools (e.g., simulations, and virtual labs) enhances my understanding of science concepts.	203	4.10	0.80
I feel more motivated to participate in science classes when digital technologies are used.	203	3.95	0.90
Online science resources (videos, animations, and simulations) improve my ability to grasp complex topics.	203	4.30	0.70
Digital technologies encourage me to explore science topics beyond the classroom.	203	4.00	0.85
I prefer learning science through traditional methods (textbooks, lectures) rather than digital tools.	203	2.40	1.10
The use of digital technologies in science teaching helps me retain information longer.	203	4.00	0.77
Technical issues (slow internet, software problems) hinder my learning experience in digital-based science lessons.	203	3.50	1.20
Collaborative digital tools (e.g., discussion forums, and group projects) enhance my engagement in science learning.	203	4.05	0.82
Digital assessments (quizzes, online tests) provide better feedback and improve my performance in science.	203	4.15	0.79

Table 2 describes the influence of digital technology on participation in science education based on 203 participants' answers. In general, the results show a positive perception of digital tools in improving the educational experience. The highest average score 4.30 is associated with the statement that online resources such as video, animation, and simulation help students understand complex topics and emphasize the effects of multimedia in science education. Similarly, digital technology has made science classes more interactive and attractive (average = 4.20), and tools such as simulation and virtual laboratory have improved understanding (average = 4.10). Students also reported that they tended to study motivation (average value = 3.95) and other topics (average = 4.00) when digital technology was used. The use of digital instruments was related to the improvement of performance using the best information preservation (average = 4.00) and digital evaluation (average = 4.15). Interestingly, the lowest average score 2.40 is recorded for the preference of traditional teaching methods, which includes a clear transition to a favorable digital approach. Nevertheless, technical problems such as the slow problems of the Internet and software have been recognized as obstacles (average = 3.50), which indicates that digital tools are useful, but to solve infrastructure and technical barriers to fully realize the potential in science education.

Table 3

Challenges and opportunities in integrating digital technologies for improving student engagement.

Description	N	Mean	Std. Dev
Limited access to digital devices and the internet is a major challenge in using digital technologies for science learning.	203	3.85	0.81
Teachers need more training to effectively integrate digital tools into science lessons.	203	3.60	0.95
Digital technologies make science learning more engaging and interactive for students.	203	4.10	0.75
Technical issues (e.g., software glitches, and poor internet connectivity) frequently disrupt digital-based science lessons.	203	3.50	1.00
The use of digital tools encourages students to explore science concepts beyond the classroom.	203	3.95	0.90
There is a lack of suitable digital content aligned with the science curriculum.	203	4.20	0.70
Students become more independent learners when digital technologies are integrated into science education.	203	3.70	0.88
The high cost of digital tools and infrastructure is a barrier to their widespread adoption in science teaching.	203	4.00	0.80
Collaboration and communication between students improve when digital technologies are used in science education.	203	3.55	1.05
Investing in digital technology for science teaching will significantly improve student engagement and learning outcomes.	203	3.90	0.85

Table 3 emphasizes the problems and functions related to the integration of digital technology to improve the students who improve the science education students. The results show a strong agreement that digital tools improve participation and interactions, as reflected in the high average score of 4.10 for a statement that emphasizes positive effects on scientific training. Similarly, students admitted that digital tools encouraged scouting outside the classroom (average = 3.95) and contributed to the student's independence (average = 3.70). But some problems have been confirmed. The most important barrier is that there is no appropriate digital content corresponding to the science curriculum (average = 4.20). The high cost of digital tools and infrastructure (average = 4.00) and access to the device must be limited and connected to the Internet (average = 3.85). Other problems include frequent technical problems (average = 3.50) and inappropriate teacher training (average = 3.60), both of which can violate or limit the effective use of digital technology. Despite these disorders, students expressed optimism in relation to the role of technology, and many believed that investment in digital tools would greatly improve participation and learning results (average = 3.90). These results emphasize the need for strategic investment and support to overcome the implementation problem and maximize the advantages of digital education.

Table 4

Factors Affecting the Use of Digital Technologies in Education.

Description	N	Mean	Std. Dev
The availability of digital devices (e.g., computers, and tablets) affects the effective use of digital technologies in education.	203	4.15	0.72
Lack of proper internet connectivity is a major barrier to using digital	203	4.00	0.85

Description	N	Mean	Std. Dev
technologies in teaching and learning.			
Teachers' digital literacy skills influence the successful integration of digital tools in the classroom.	203	3.90	0.90
Students' interest and willingness to use digital technologies impact their engagement in digital-based learning.	203	4.25	0.65
Institutional support, such as training and funding, is crucial for the effective adoption of digital technologies in education.	203	4.10	0.78
Technical issues (e.g., software malfunctions, and device compatibility) hinder the smooth use of digital learning tools.	203	3.95	0.89
Parental support and encouragement play a role in students' access to and use of digital technologies for learning.	203	4.20	0.75
The cost of digital tools and subscriptions affects their widespread adoption in schools.	203	4.05	0.80
Security and privacy concerns influence the willingness of educators and students to use digital technologies.	203	3.85	1.00
The effectiveness of digital technologies depends on how well they are integrated with traditional teaching methods.	203	4.00	0.82

Table 4 examines the factors influencing the use of digital technologies in education, revealing a generally strong agreement among respondents on their importance. The highest mean score (4.25) was attributed to students' interest and willingness to use digital tools, highlighting that learner motivation plays a crucial role in effective technology integration. Other highly rated factors included the availability of digital devices (mean = 4.15), parental support (mean = 4.20), and institutional support such as training and funding (mean = 4.10), all of which contribute significantly to successful adoption. Internet connectivity was also seen as a major barrier (mean = 4.00), reinforcing previous concerns about access. Similarly, the cost of digital tools and subscriptions (mean = 4.05) and technical issues (mean = 3.95) were noted as limiting factors. Teachers' digital literacy (mean = 3.90) and concerns about security and privacy (mean = 3.85) also influenced the willingness to adopt digital technologies. Importantly, respondents agreed that the effectiveness of digital tools depends on how well they are integrated with traditional methods (mean = 4.00), suggesting that a blended approach may be most beneficial. These findings emphasize that both technological infrastructure and human factors must be addressed to optimize digital learning environments.

Table 5

Independent Samples T-test (Gender Differences in Engagement)

Group	N	Mean Engagement	Std. Dev
Male	50	4.05	0.41
Female	50	4.20	0.38

Table 5 shows the results of the independent samples of the T-test by analyzing the gender differences in interaction with the digital technology of students. According to the data, students students reported the average interaction evaluation (4.20) and 0.38 and 0.41, compared to boys (4.05), respectively. The difference is humble, but women suggest that women can feel more positive when using digital tools in science education. Factors such as learning preference, resource access, or trust in technology use can affect this small diversification. The data obtained indicates the potential value of consideration of gender approach or support strategy to ensure fair participation in digital education.

Table 6

Correlation (Engagement vs. Challenges and Factors)

Variables	r	p
Engagement & Challenges	-0.42	0.003
Engagement & Factors	0.60	<0.001

Table 6 shows the correlation analysis between the two major variables: the problem related to the student's participation, the use of digital technology, and the influential factors. The results show a medium-oriented correlation between participation and problems (r = -0.42, p = 0.003). This indicates that there is a tendency to decrease technical problems, lack of resources, or increase content alignment. On the contrary, there is a strong positive correlation between participation and influential factors (R = 0.60, p &t;0.001), which suggests that participation has been greatly improved if there are support factors such as the availability of the device, teacher education, and student's interest. The two correlation relationships are statistically significant and emphasize that in science education, digital technology must minimize obstacles and strengthen the terms of the clause to increase students' interactions.

Table 7

Linear Regression

Dependent Variable: Engagement

Predictors: Challenges, Factors, Usage Frequency

Predictor	Beta	p-value
Challenges	-0.31	0.007
Factors	0.52	<0.001
Usage Frequency	0.29	0.012

Model R^2 = 0.48

Table 7 shows the results of linear regression analysis. This studies the prognosis of three problems, factors, and frequency of use in the field of interaction with digital technology in science education. This model describes 48%of distribution in interaction (r^2 = 0.48), which represents a moderately strong prognosis connection. Among the predictive variables, the factors (eg, the availability of the device, the interest of the student, the institutional support) had the most positive effect on participation and emphasized an important role in stimulating effective digital learning. The frequency of use also positively predicts interaction (î^2 = 0.29, p = 0.012), which suggests that more frequent use of digital tools is related to higher-level interactions. On the contrary, the problem has had a negative impact on participation (î^2 = -0.31, p = 0.007), and has strengthened the idea that barriers such as technical problems and lack of access can significantly reduce their participation. These results show that teachers and institutions should focus on improving support factors and reducing problems in order to increase participation, and encourage regular and significant use of digital technology.

Discussion

The results of this study provide valuable information on how digital technology affects students. The results are consistent that digital tools are motivated to improve the learning experience, make lessons more interactive, improve conceptual understanding, and motivate students to participate more actively. Regarding the high average scores of Table 2, especially online resources and simulations, students confirm that they consider more effective technical education than traditional methods. The preference for traditional approaches is emphasized as a change in the preference for learning among the current generations. Popularity, most respondents were 15-year-old students and were students with a lot of numbers using digital devices every day, which can contribute to the comfort of acquaintances and technology. This can partially explain the interaction indicators between women as shown in Table 5. However, if there is a large portion of the students who do not have access to the digital tool, it shows the current digital gap, which can affect capital and learning results.

Tables 3 and 4 show a double reality. Students recognize the advantages of digital learning, but they experience limited access, high cost, and inappropriate content or infrastructure. Problems, such as poor connections and lack of teaching teachers, were moderately high, suggesting that they could not fully realize potential technical potential without solving these problems. Correlation and Regression Analysis (Tables 6 and 7) provide a deeper statistical verification of this relationship. The negative correlation between participation and the problem confirms that the barrier reduces the effects of digital education. On the contrary, the strong positive correlation between the interaction factors and the provisions emphasizes the importance of support conditions such as institutional support, student motivation, and device availability when promoting successful integration.

Ultimately, this study shows that digital technology has significant prospects for changes in science education, but its impact depends on fair approach, preparation of infrastructure and educational support. The results require a balanced approach, which systematically solves the problem of not only contributing to the use of digital tools, but also preventing a wide range of and effective acceptance.

Conclusion

This study concludes that digital technology plays an important role in enhancing students' participation in science education. Most students reported that when using digital tools such as simulation, online resources and co -platforms, interaction, motivation, and understanding of complex concepts increased. Despite the fact that there is a clear preference for digital learning compared to traditional methods, some barriers, such as limited access to devices and the Internet, high cost, and technical difficulties, continue to prevent effective implementation. Gender analysis showed slightly higher participation among students, and it was confirmed that it was important to maximize the participation of correlation and regression analysis that contributed to the decrease and level of problems. In general, this study emphasizes the need for strategic investment, infrastructure development, and expertise to ensure digital technology effective and fair integration in science education, which ultimately improves students' learning and autonomy.

Recommendations

- Future studies can expand beyond a single district to multiple regions or provinces to gain more generalized and comparative insights.
- Researchers may include other science subjects such as Chemistry, Biology, and Mathematics to compare how digital technologies impact engagement across different disciplines.
- Future studies could focus on comparing the effectiveness of various digital tools (e.g., virtual labs, simulations, educational apps, and online collaborative platforms).
- Investigate the barriers (technological, financial, and institutional) that hinder the effective use of digital technologies in science classrooms.
- Future researchers can focus on suggesting practical, evidence-based policies for educational institutions and government bodies to integrate digital technology effectively.

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