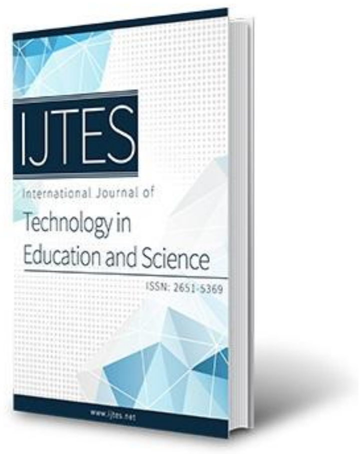

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Hafiz Muhammad Ihsan Zafeer
Zhejiang Normal University, China

Samra Maqbool
Smart Learning Institute of Beijing Normal University, China

Yu Rong
Zhejiang Normal University, China

Sufyan Maqbool
Zhejiang Normal University, China

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Hafiz Muhammad Ihsan Zafeer, Samra Maqbool, Yu Rong, Sufyan Maqbool

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Abstract

The integration of digital learning tools in school science classes has garnered significant attention, prompting an investigation into their effects on student engagement and achievement. This study examines the impact of students' access to technology, teachers' digital competency, and the frequent use of digital tools on the engagement and academic performance of middle school students in science subjects. Utilizing a cross-sectional survey design, data were collected from 309 middle school science teachers across 45 public schools in Punjab, Pakistan, through validated, self-administered questionnaires. Six hypotheses were formulated and tested using SPSS and SmartPLS. The findings indicate that access to technology, teachers' digital competency, and the frequent use of digital tools positively influence student engagement and achievement in science. Digital tools significantly enhance engagement by providing interactive and personalized learning experiences, leading to increased motivation and interest among students. Furthermore, improved academic outcomes are evident in higher test scores and performance in science assessments. Teachers also noted a positive shift in classroom dynamics, characterized by increased collaboration and inquiry among students. These results highlight the critical need for ongoing investment in educational technology and professional development for educators to fully leverage the benefits of digital learning tools.

Introduction

Digital learning tools have revolutionized the educational landscape, offering innovative ways to enhance student engagement and achievement. These tools, ranging from interactive software and educational apps to virtual classrooms and online resources, provide students with dynamic and personalized learning experiences. (Hattie, 2008; Wang et al., 2024). However, Student access to technology plays a crucial role in enhancing engagement and achievement in science learning. Digital tools and resources enable students to interact with scientific concepts through simulations, experiments, and visualizations, which can deepen understanding and spark interest (Olugbade et al., 2024). Recent studies show that technology-supported science education can personalize learning experiences and improve problem-solving skills (Zhao et al., 2021). Equitable access to these technologies helps ensure that all students have the opportunity to excel in science (Leonard et al., 2016).

Further, a teacher's digital competency is crucial for fostering student engagement and achievement in science learning. When educators effectively integrate digital tools into their teaching practices, they enhance interactive and personalized learning experiences, which can boost student motivation and understanding (Gameil & Al-Abdullatif, 2023). Studies highlights that teachers with strong digital skills are better equipped to use technology to facilitate hands-on experiments and real-time feedback, leading to improved science outcomes (Chigona et al.). As digital tools continue to advance, teachers' ability to leverage these technologies becomes increasingly vital for student success in science.

Moreover, the frequency of digital tool usage significantly impacts student engagement and achievements in science learning. Regular use of digital tools, such as interactive simulations and virtual labs, has been shown to enhance students' active participation and comprehension of scientific concepts (Hwang et al., 2023). Studies reveal that consistent integration of these tools into science curricula promotes deeper learning and better problem-solving skills (Chen et al., 2024). Additionally, frequent exposure to digital resources helps maintain student interest and motivation, leading to improved academic outcomes (Garrison et al., 2023). As technological advancements continue, their integration into science education remains increasingly important.

However, in Pakistan's middle school science classes, several challenges hinder the effective use of digital learning tools and impact student engagement and achievement. Limited student access to technology, coupled with varying levels of teacher digital competency, creates disparities in learning opportunities. Additionally, inconsistent frequency of digital tool usage further exacerbates these challenges, leading to suboptimal educational outcomes. Identifying and addressing these barriers is essential for improving the integration and effectiveness of digital tools in enhancing science education. Thus, the current study aimed to investigate the impact of student access to technology, teacher digital competency, and frequency of digital tool usage on student engagement and achievement in middle school science classes in Pakistan. Based on study’s aim following two research questions were formulated: (1) how does the integration of digital learning tools such as student access to technology, teacher digital competency, and frequency of digital tool usage impact student engagement in middle school science classes? (2) What is the relationship between student access to technology, teacher digital competency, and frequency of digital tool usage and student achievement in middle school science classes?

Theoretical Perspective

The theoretical perspective on the relationship between student access to technology, teacher digital competency, and frequency of digital tool usage with student engagement and achievements in science is grounded several educational theories. Constructivist theory emphasizes that learners construct their understanding through interaction with their environment and active engagement (Mann & MacLeod, 2015). Digital tools can facilitate constructivist learning by providing interactive and experiential learning opportunities, which can enhance student engagement and achievement in science (Cetin-Dindar, 2015). Further, Technological Pedagogical Content Knowledge (TPACK) framework, developed by Tanak (2020) and highlights the importance of teachers' ability to integrate technology effectively with pedagogy and content knowledge. Teacher digital competency, as part of the TPACK framework, plays a critical role in leveraging digital tools to improve student engagement and academic outcomes (Graham, 2011; Koehler et al., 2013). Engagement theory suggests that for students to achieve academic success, they need to use digital tools frequently and actively engaged in their learning process. Digital tools can provide engaging and interactive experiences that align with this theory, potentially improving both engagement and achievement in science (Henrie et al., 2015; Khan et al., 2017).

Literature Review

Access to Technology and Students' Engagement and Achievement in Science Classes

Access to technology has increasingly been recognized as a crucial factor in enhancing student's engagement and achievement in science education. Digital tools such as simulations, virtual labs, and interactive software provide students with opportunities to explore scientific concepts in a more hands-on and engaging manner (Potkonjak et al., 2016). These tools allow students to visualize abstract concepts, conduct experiments in a virtual environment, and engage with content that may otherwise be inaccessible in a traditional classroom setting (Chen et al., 2020). Research by Lee et al. (2024) indicates that when students have regular access to these technologies, their engagement levels increase significantly, leading to a deeper understanding of scientific principles. Moreover, the integration of technology in science education has been shown to positively impact students' academic achievement (Lei & Zhao, 2007; Major et al., 2021; Taylor et al., 2024). Studies have found that access to digital resources enables personalized learning, where educational content is tailored to meet individual students' needs, thereby improving learning outcomes (Lee et al., 2018). For instance, adaptive learning platforms can adjust the level of difficulty based on a student's progress, offering additional support or challenges as needed. According to Ingkavara et al. (2022), personalized approach not only helps in mastering science content but also supports the development of critical thinking and problem-solving skills, which are essential in science education.

A study conducted by Warschauer et al. (2004), who explored the role of technology in supporting students' academic success. They found that access to technology in the classroom not only enhanced student engagement by providing interactive and personalized learning experiences but also contributed to improved academic outcomes. Similarly, Hohlfeld et al. (2008) conducted a study that examined the digital divide in K-12 public schools and its effect on student achievement in science. They found that students with better access to digital tools and resources demonstrated higher levels of engagement and achieved better academic results in science subjects. More recent research by Srivastava and Bag (2023) further explored the impact of technology access on student engagement and achievement in science education. Their findings revealed that students who had regular access to digital learning tools were more engaged in science activities and performed better academically compared to those with limited access. However, the benefits of technology in science education are not uniformly experienced by all students, largely due to the digital divide (Cullen, 2003). Disparities in access to technology, particularly in underprivileged and rural areas, continue to pose significant challenges (Salemink et al., 2017). Students who lack access to digital tools are often at a disadvantage, missing out on the enhanced learning experiences that their peers enjoy (Waycott et al., 2010). The inequity can lead to gaps in both engagement and achievement in science subjects. Addressing these disparities is crucial, as emphasized by Warschauer and Matuchniak (2010), to ensure that all students can benefit from the opportunities that technology offers in enhancing science education.

Teacher Digital Competency and Students’ Engagement and Achievement in Science Classes

Teacher digital competency plays a pivotal role in shaping students' engagement and achievement in science classes. Teachers who possess strong digital skills are better equipped to integrate technology effectively into their lessons, creating more interactive and engaging learning experiences (Falloon, 2020). For example, teachers can use digital tools such as simulations, virtual labs, and data analysis software to facilitate a deeper understanding of scientific concepts. Previous researches have shown that when teachers are competent in using these technologies, students are more likely to participate actively in class and demonstrate increased curiosity and interest in science subjects (Canal et al., 2024; Chigona et al.; Howard et al., 2021; Mohamad Nasri et al., 2023). Furthermore, teacher digital competency directly influences students' academic achievement in science (Elstad & Christophersen, 2017; Maqbool, Wei, et al., 2020). Competent teachers can personalize learning experiences by leveraging digital tools to meet the diverse needs of their students (Ally, 2019; Draissi et al., 2025). They can use adaptive learning platforms to provide tailored feedback, assign individualized tasks, and track student progress in real-time (Srinivasa et al., 2022). The ability to customize instruction helps address different learning paces and styles, leading to improved academic performance.

Research by Mishra et al. (2012) highlights that students taught by digitally proficient teachers tend to perform better on assessments and exhibit a stronger grasp of scientific concepts compared to their peers. As emphasized by Adnan et al. (2024) schools must prioritize such training to ensure that teachers can keep pace with technological advancements and effectively apply them in their science classrooms. Hennessy et al. (2005) revealed that the role of teacher digital competency in secondary science education. Their research found that teachers who effectively used technology in their science classes were able to foster greater student engagement, as digital tools provided more interactive and exploratory learning opportunities. Likewise, Tondeur et al. (2023) further explored the link between teacher digital competency and student outcomes in science education. They found that teachers who participated in such programs were more confident in using digital tools and were able to create more engaging and personalized learning experiences for their students. However, the benefits of teacher digital competency are contingent upon ongoing professional development and support (Rehman et al., 2025). Even with access to advanced digital tools, teachers may struggle to use them effectively without proper training and resources. Continuous professional development programs that focus on enhancing digital skills and integrating technology into science teaching are crucial for maximizing the impact of digital tools on student engagement and achievement.

Frequent Use of Digital Tools and Students’ Engagement and Achievement in Science Classes

The frequent use of digital tools in science classes has been shown to significantly enhance students’ engagement and academic achievement. According to Xie et al. (2019) students who regularly engage with these digital resources are more likely to be actively involved in learning activities, leading to increased curiosity and sustained interest in science subjects. Research by Howard et al. (2016) suggests that consistent interaction with digital learning platforms enhances students' ability to grasp complex scientific concepts, resulting in better performance on assessments and a deeper understanding of the material. These tools provide immediate feedback, which helps students correct their mistakes and reinforce their learning in real time. As highlighted by Rutten et al. (2012) the effectiveness of digital tools in enhancing student engagement and achievement depends on how they are integrated into the curriculum and whether they are used purposefully. Simply increasing screen time without a clear educational objective can lead to disengagement and even negatively impact learning outcomes. Sung et al. (2016) explored the effect of digital learning tools on student outcomes in science education. Their research found that students who used digital tools frequently in their science classes exhibited higher levels of engagement, as the interactive nature of these tools made learning more dynamic and accessible. Another significant study by Fernandes et al. (2020) examined how the regular integration of digital tools influences academic achievement in science subjects. Their research highlighted that frequent use of digital tools, such as simulations and interactive quizzes, not only increased student engagement but also led to improved performance on science assessments (Maqbool, Sarwar, et al., 2020; Zafeer et al., 2020).

The study also emphasized that these tools support the development of critical thinking and problem-solving skills, which are essential in understanding complex scientific concepts. The literature consistently demonstrates that the students' access to technology, teachers' digital competency and frequent use of digital tools in science classes significantly enhances both student engagement and academic achievement. While the frequent use of digital tools presents substantial benefits for student engagement and achievement in science classes, it is crucial that educators receive adequate training and support to integrate these technologies effectively. As digital tools continue to evolve, their potential to transform science education and improve student outcomes. The current study conceptual model was made based on the literature review that showed in Figure 1. The conceptual model depicting the relationship between the independent variables (Student Access to Technology, Teacher Digital Competency, and Frequency of Digital Tool Usage) and the dependent variables (Student Engagement and Student Achievement). The arrows illustrate the impact of the independent variables on the dependent variables. Grounded in the research questions, literature review, and conceptual framework, six hypotheses (H1, H2, H3, H4, H5, and H6) have been formulated, as outlined below.

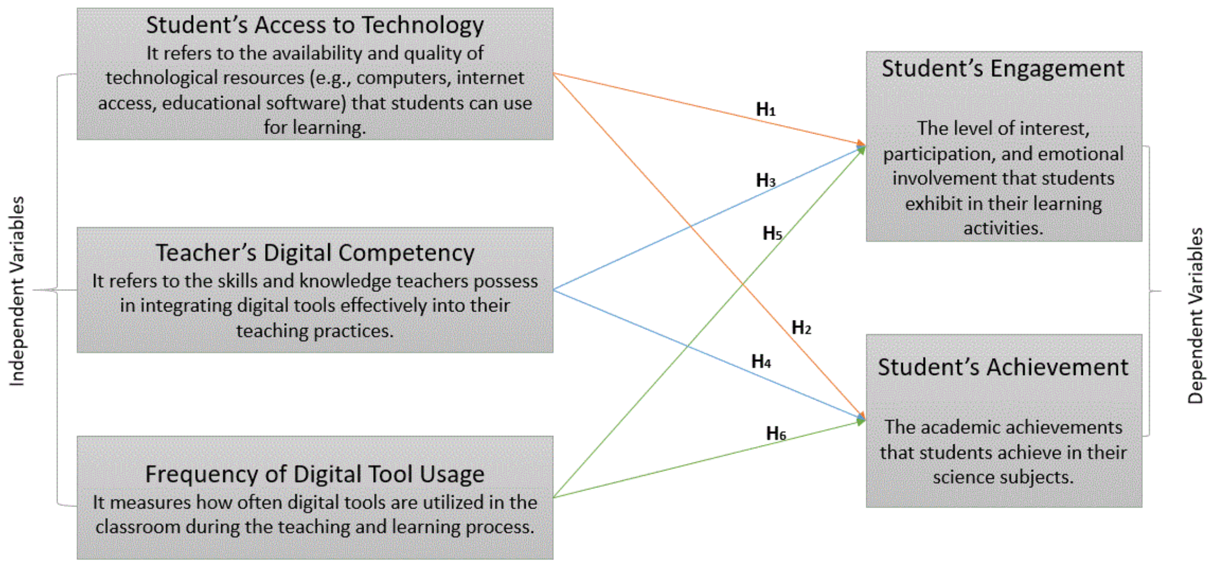

Figure 1. Conceptual model of current study (source: Author Conceptualization)

Study Hypothesis

H1: There is impact of student's access to technology on student's engagement.
H2: There is impact of student's access to technology on student's achievement.
H3: There is impact of teacher's digital competency on student's engagement.
H4: There is impact of teacher's digital competency on student's achievement.
H5: There is impact of frequent digital tools usage on student's engagement.
H6: There is impact of frequent digital tools usage on student's achievement.

Methodology

The current study was utilized a cross-sectional survey research design (Samra Maqbool, Hafiz Muhammad Ihsan Zafeer, Sufyan Maqbool, et al., 2024; Van der Stede, 2014; Wang & Cheng, 2020) to quantitatively assess the impact of digital learning tools. The design allows for the collection of data from a large sample at a single point in time, facilitating the exploration of relationships between the independent variables (access to technology, teacher digital competency, and frequency of digital tool usage) and the dependent variables (student engagement and achievement).

Participants

The study involved a total of 309 middle school science teachers from the Punjab province who participated in a cross-sectional survey. These teachers were selected using a random sampling procedure (Maqbool et al., 2023; Zafeer et al., 2023) to ensure a representative sample across the province. All participants were experienced educators, with a background in teaching science subjects at the middle school level. The diverse experiences and teaching environments of these participants provided a comprehensive understanding of how digital learning tools impact on students engagement and achievements in science classes.

Instruments

In the current study, the researcher utilized a combination of adopted and self-administered questionnaires to assess the impact of digital learning tools on student engagement and academic achievement in science classes. The self-administered Technology Access Questionnaire was utilized to assess students' access to technology. It included three statements that examined the availability of devices such as laptops and tablets, internet connectivity at home, and students' access to digital resources provided by the school. The study also incorporated a Teacher Digital Competency Survey, a validated instrument consisting of four statements, to evaluate teachers' digital competency (Falloon, 2020). The survey assessed teachers' confidence, technical skills, and the frequency with which they integrated digital tools into their science instruction.

Additionally, the Digital Tool Usage Survey was custom-designed to evaluate the frequency and types of digital tools used in science classes (Swathi, 2022). The survey comprised five statements regarding the use of specific tools, such as simulations, virtual labs, and educational apps, and the frequency with which these tools were utilized. The Student Engagement Survey Questionnaire (SESQ), a validated instrument, was adapted to include four statements measuring behavioral, emotional, and cognitive engagement specifically within science courses. The SESQ has been extensively employed in educational research to assess various dimensions of student engagement. Finally, to assess academic achievement, teachers were asked to evaluate their satisfaction with students' performance in science courses. The evaluation was based on four specific statements. The survey questionnaires can be seen in Table 1. Three five-point Likert scales were employed to evaluate the questionnaire responses. The first scale ranged from 1 (strongly disagree) to 5 (strongly agree), the second from 1 (never) to 5 (always), and the third from 1 (poor) to 5 (excellent).

Table 1. Survey Questionnaire used in Current Study

No	Variables codes	Statements
	SAT	
1		Most students in my class have regular access to devices (e.g., laptops, tablets) necessary for completing their digital assignments and participating in online learning activities.
2		Students in my class generally have reliable and adequate internet connectivity at home for participating in online classes and accessing digital resources.
3		Students in my class have consistent access to the digital resources and educational tools provided by the school, including necessary software and online platforms.
	TDC	
4		I feel confident in my ability to effectively integrate digital tools, such as simulations and educational software, into my science lessons.
5		I regularly use digital tools to create interactive and engaging science activities for my students.
6		I am proficient in troubleshooting technical issues that arise when using digital tools during science lessons.
7		I frequently update my knowledge and skills regarding the latest digital tools and resources available for science teaching
	FDTU	
8		I often use simulations (e.g., virtual experiments or interactive models) during my science lessons.
9		I use virtual labs to conduct experiments and explore scientific concepts in my science classes.
10		Educational apps or software are integrated into my science teaching on a regular basis.
11		I often use digital tools like videos or animations to help understand science topics.
12		I use online quizzes or assessment tools to test my understanding of science concepts.
	SE	
13		My students do effort into completing all the tasks and activities during science lessons

No	Variables codes	Statements
		that involve using digital tools.
14		My students enjoy using digital tools, like simulations or interactive apps, in my science classes.
15		My students often think deeply about the science concepts when using digital resources, such as virtual labs or educational software.
16		My students actively participate in class discussions and activities when digital tools are used in science lessons.
	SA	
17		How do you rate students' science course's scores?
18		How do you rate students' science scores?
19		How do you rate students' computer science scores?
20		How do you rate students' mathematic scores?

Note: SAT = student's access to technology, TDU = teacher's digital competency, FDTU = frequency of digital tools usage, SE = student's engagement, SA = student's achievement.

Data Collection and Pilot Testing of the Survey Questionnaire

The participants in this study were science teachers from public middle schools in Punjab, Pakistan. Data collection took place on pre-arranged dates at the respective schools. Upon meeting the participants, the purpose of the study was explained, and written consent was obtained prior to their participation. Survey questionnaires were then distributed to the participants, who were requested to complete them. Participants were also informed that all information collected would remain confidential and be used solely for research purposes. For pilot testing, data were initially collected from 68 participants prior to the formal data collection phase. To assess the reliability of the questionnaire, the data were entered into the statistical software SPSS, where Cronbach's alpha was calculated. The overall resulting value of Cronbach's alpha was 0.89 that indicates satisfactory reliability, as supported by previous studies in the literature (Zafeer et al., 2022), and thus deemed appropriate for proceeding with formal data collection.

Statistical Analysis

Two statistical software programs, SPSS and SmartPLS, were used to analyze the collected data. SPSS was employed to analyze the reliability and demographic characteristics of the participants. To validate the measurement model and conduct path analysis, the latest version of SmartPLS was utilized (Samra Maqbool, Hafiz Muhammad Ihsan Zafeer, Pingfei Zeng, et al., 2024; Zafeer et al., 2024). These tools provided comprehensive insights into the reliability, structural validity, and relationships of digital learning tools such as; students' access to technology, teacher's digital competency and frequency of digital tool u as independent variable, while students engagement and students' achievement as dependent variables.

Findings

In Table 2 the data presents demographic and professional characteristics of a sample consisting of 309 individuals. The age distribution shows that the majority of participants are between 31-35 years old (45.3%), followed by those aged 36-40 years (40.1%), with a smaller group aged 25-30 years (14.6%). In terms of gender, the sample is predominantly male, with 69.3% identifying as male and 30.7% as female. When examining the subjects taught, the largest proportion of participants teach Computer Science (45.0%), followed by Science (33.7%), and Mathematics (21.4%). Regarding years of experience, nearly half of the participants (49.9%) have 6-10 years of teaching experience, 34.6% have 0-5 years, 15.9% have 11-15 years, and only a small fraction (2.6%) have more than 15 years of experience. The overview provides insights into the composition of the sample in terms of age, gender, teaching specialization, and professional experience.

Table 2. Description of Demographic Variables with Frequency and Percentage

Variables	F	(%)
Age		
25-30	45	14.6
31-35	140	45.3
36-40	124	40.1
Total	309	100.0
Gender		
Male	215	69.3
Female	95	30.7
Total	309	100.0
Teaching Subjects		
Science	104	33.7
Computer Science	139	45.0
Mathematics	66	21.4
Total	309	100.0
Experience		
0-5	107	34.6
6-10	145	49.9
11-15	49	15.9
Above 15	8	2.6
Total	309	100.0

Note: F = frequency, (%) = percentage

Measurement Model's Assessment

The Table 3 presents metrics assessing the internal consistency of a structural model, focusing on factors such as student access to technology, teacher digital competency, frequency of digital tool usage, student engagement, and student achievements. The measurement model shown in Figure 2 was generated by executing the PLS algorithm. Factor loadings (λ) range from 0.552 to 0.891, indicating varying levels of item reliability within each construct. The Variance Inflation Factors (VIF) are all close to 1, which supports the model's stability (Sufyan Maqbool et al., 2024; Rehman et al., 2024). Composite Reliability (CR) values exceed 0.75 (Cheung et al., 2024; Zafeer et al., 2025), and Cronbach's Alpha (α) values are all above 0.75, suggesting good internal consistency (Taber, 2018). Average Variance Extracted (AVE) values are above the 0.5 threshold, confirming adequate convergent validity (dos Santos & Cirillo, 2023; Zafeer et al., 2022).

Table 3. Metrics for Internal Consistency in Structural Model

Variables	Codes	Loadings (λ)	VIF	CR	Alpha(α)	AVE
Student's Access to Technology						
	SAT1	0.552	1.008	0.768	0840	0.531
	SAT2	0.791	1.089			
	SAT3	0.815	1.095			
Teacher's Digital Competency						
	TDC1	0.748	1.073	0.845	0.759	0.578
	TDC2	0.769	1.016			
	TDC3	0.696	1.473			
	TDC4	0.822	1.028			
Frequency of Digital Tool Usage						
	FDTU1	0.873	1.079	0.919	0.890	0.697
	FDTU2	0.823	1.239			
	FDTU3	0.715	1.095			
	FDTU4	0.891	1.097			
	FDTU5	0.859	1.098			
Students Engagement						
	SE1	0.670	1.264	0.817	0.78	0.527
	SE2	0.737	1.061			
	SE3	0.742	1.213			
	SE4	0.752	1.056			
Student's Achievements						
	SA1	0.727	1.273	0.815	0.784	0.525
	SA2	0.673	1.029			
	SA3	0.721	1.348			
	SA4	0.774	1.035			

The Heterotrait-Monotrait (HTMT) ratio results indicate the discriminant validity among the constructs "Student's Access to Technology" (SAT), "Teacher's Digital Competency" (TDC), "Frequency of Digital Tool Usage" (FDTU), "Students' Engagement" (SE), and "Student's Achievements" (SA). The HTMT values between constructs are all below the commonly accepted threshold of 0.85 (Henseler et al., 2015) with the highest value being 0.835 between SAT and TDC. These results in Table 4 suggest that the constructs are sufficiently distinct from each other, indicating strong discriminant validity in the model, thereby supporting the robustness of the constructs in measuring different aspects of educational technology and its impact on students.

Table 4. Discriminant Validity through Heterotrait-monotrait ratio (HTMT) Rules

Variables	SAT	TDC	FDTU	SE	SA
SAT	0.835				
TDC	0.373	0.724			
FDTU	0.354	0.323	0.729		
SE	0.339	0.275	0.287	0.726	
SA	0.352	0.272	0.226	0.472	0.760

Note: SAT = students access to technology, TDU = teachers' digital competency, FDTU = frequency digital tools usage, SE = students' engagement, SA = students' achievement

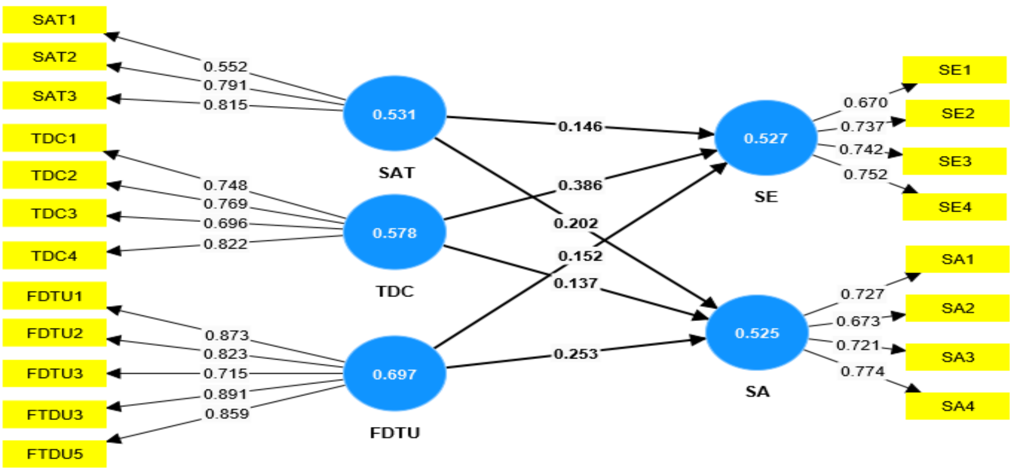

Figure 2. Measurement Path Analysis Model

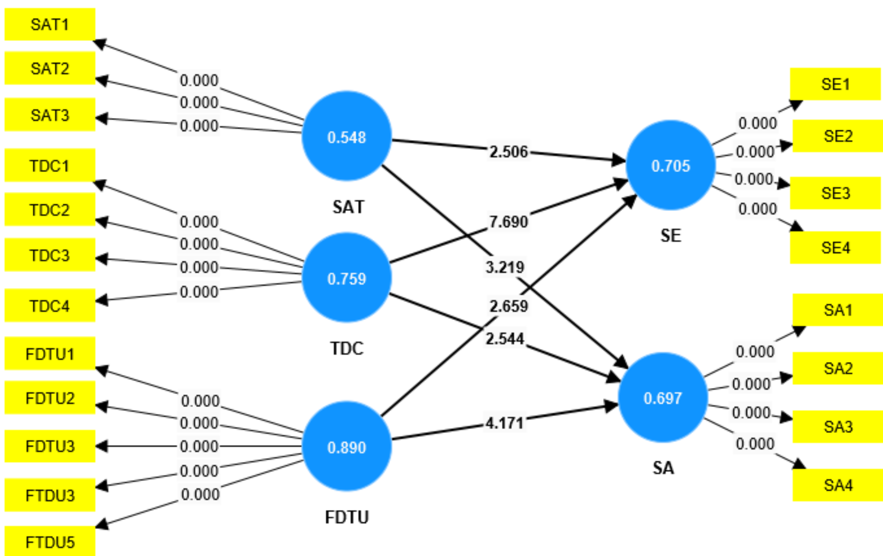

Figure 3. Bootstrap Model for Path Analysis

Elaboration of Path Analysis and Hypothesis Testing

The path analysis results in Table 5 and Figure 3 highlight significant relationships between the variables in the study, as evidenced by the path coefficients (β), T-values, and p-values. All hypothesized relationships were accepted, indicating that "Student's Access to Technology" (SAT) positively impacts both "Student's Achievements" (SA) and "Students' Engagement" (SE) with β values of 0.202 and 0.146, respectively. Similarly, "Teacher's Digital Competency" (TDU) and "Frequency of Digital Tool Usage" (FDTU) also positively influence SA and SE, with FDTU showing a particularly strong effect on SA (β = 0.253). The p-values for all relationships are below 0.05, confirming the statistical significance of these paths (Hair Jr et al., 2020). These findings underscore the critical role of both student access to technology and teacher digital competency in enhancing student engagement and achievement in educational settings.

Table 5. Hypothesis Testing Using Path Analysis

Relationship	Path Coefficients	β	T	P	2.5%	97.5%	Decision
SAT → SA	0.202	0.063	3.219	0.000	0.081	0.327	Accepted
SAT → SE	0.146	0.058	2.506	0.008	0.034	0.262	Accepted
TDU → SA	0.137	0.054	2.544	0.001	0.033	0.242	Accepted
TDU → SE	0.386	0.050	7.690	0.012	0.285	0.484	Accepted
FDTU → SA	0.253	0.061	4.171	0.011	0.133	0.374	Accepted
FDTU → SE	0.152	0.057	2.659	0.000	0.039	0.264	Accepted

Note: β = beta value, T = t-statistics, P = p-values

The fit indices in Table 6 for the measurement model indicate an overall acceptable fit. The SRMR (Standardized Root Mean Square Residual) value of 0.061 reflects a good fit, as values below 0.08 are generally considered acceptable (Zheng & Bentler, 2024). The Chi-square statistic was also significant (Martynova et al., 2018). The Normed Fit Index (NFI) of 0.910 surpasses the recommended threshold of 0.90, further supporting the model's adequacy (Goretzko et al., 2024). Taken together, these indices suggest that the model demonstrates a reasonable fit to the data.

Table 6. Fit Indices for Measurement Model

Fit Indices	Model Fit obtained Values
SRMR	0.061
Chi-square	549.820
NFI	0.910

Note: SRMR = standardized root mean square residual, X2 = chi-square, NFI = Normed Fit Index

Discussion

The findings of this study align with the growing body of research highlighting the positive influence of digital learning tools on student engagement and achievement, particularly in middle school science classes. Access to technology plays a crucial role in this dynamic, as it serves as the foundation for students to interact with digital tools. Research shows that when students have consistent and equitable access to technology, they are more likely to engage deeply with learning materials and participate actively in classroom activities (Alieto et al., 2024; Kulal et al., 2024; Le Pichon et al., 2024; Maqbool et al., 2022; Zafeer et al., 2021). The increased engagement is linked to a greater sense of ownership over their learning process, which, in turn, leads to improved academic outcomes (Bianchini & Cavazos, 2007; Farley & Burbules, 2022; Javed et al., 2024).

However, teacher digital competency also emerged as a significant factor influencing student outcomes. In an era where technology is integral to education, teachers' ability to effectively integrate digital tools into their teaching practices is critical (Bereczki & Kárpáti, 2021). As per the study of Basilotta-Gómez-Pablos et al. (2022) who indicate that teachers who are proficient in using technology can create more interactive and dynamic learning environments, which foster student engagement. Similarly, Allman et al. (2023) examined the impact of teachers' digital competency on student engagement and achievement in science classes. The findings revealed that when teachers possess high digital competency, they are better able to integrate technology into their teaching practices, which significantly enhances student engagement and leads to improved academic outcomes in science education. Likewise, Ng et al. (2023) explored how teachers' proficiency with digital tools influences student engagement and achievement in science classes. The research concluded that teachers who are proficient in using digital resources can create more interactive and engaging learning environments, resulting in higher student achievement. These environments often feature personalized learning experiences, where students can work at their own pace and explore topics in greater depth. The result is a more motivated and engaged student body, which ultimately enhances achievement, particularly in subjects like science that benefit from hands-on and exploratory learning approaches.

Additionally, the frequency of digital tools usage is another key element that impacts student engagement and achievement. Regular use of digital tools allows students to become more familiar with the technology, reducing the cognitive load associated with learning new tools and enabling them to focus on the content. Research conducted by Kong (2015) supports the idea that consistent use of technology in the classroom helps students develop critical thinking and problem-solving skills, which are essential for success in science education. Another study conducted by Schindler et al. (2017) frequent use of digital tools, when integrated effectively into lessons, significantly increased student engagement, which was directly associated with higher academic achievement. The research emphasized that regular, thoughtful use of technology enhances students' learning experiences and outcomes. Huang et al. (2023) explored how the regularity of digital tools usage in instruction impacts student achievement. The study concluded that consistent and purposeful use of digital tools in educational activities promotes active learning and better academic results, particularly in subjects requiring high levels of engagement, such as science. Thus, frequent interaction with digital tools can make learning more enjoyable and accessible, which can lead to higher levels of student engagement and better academic performance.

Limitations and Future Research Directions

The current study encountered several limitations. A significant challenge was the uneven access to technology, which resulted in inconsistent outcomes across different regions and socio-economic backgrounds. Additionally, the effectiveness of these tools was often dependent on the varying levels of teacher proficiency and training, affecting how well these tools were utilized in the classroom. The study's short-term nature also limited the understanding by not capturing the long-term effects and sustained benefits of digital learning tools. Future research should have focused on conducting longitudinal studies to evaluate the enduring impact of digital tools, investigating how disparities in technology access influenced educational outcomes, and examining the role of teacher training in optimizing the use of digital resources. These approaches could have provided deeper insights into how digital tools affected student engagement and achievement over time and across diverse contexts.

Conclusion

The study reinforces the importance of integrating technology into middle school science education, not only by providing students with access to digital tools but also by ensuring that teachers are well-equipped to use these tools effectively. The positive relationship between technology access, teacher competency, and digital tool usage frequency with student engagement and achievement underscores the need for continued investment in educational technology and professional development for educators. As digital learning tools continue to evolve, it is crucial to stay abreast of the latest developments and ensure that both students and teachers are supported in this digital transformation.

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Author Information

Hafiz Muhammad Ihsan Zafeer
https://orcid.org/0000-0002-8757-9478
College of Education
Zhejiang Normal University
Jinhua, Zhejiang 321004
China

Samra Maqbool
https://orcid.org/0000-0001-5958-3800
Smart Learning Institute of Beijing Normal University
Haidian, Beijing 100875
China
Contact e-mail: *samramaqbool@bnu.edu.cn*

Yu Rong
https://orcid.org/0009-0004-8007-9202
College of Education
Zhejiang Normal University
Jinhua, Zhejiang 321004
China

Sufyan Maqbool
https://orcid.org/ 0009-0007-6290-1305
College of Education
Zhejiang Normal University
Jinhua, Zhejiang 321004
China