

IMPACT OF DIGITAL EQUITY ON TECHNO-LITERACY AMONG MARGINALIZED STUDENTS IN PUBLIC SCHOOLS OF SINDH, PAKISTAN FOR INCLUSIVE AND SUSTAINABLE EDUCATION

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ABSTRACT

Digital equity is a critical prerequisite for fostering techno-literacy and achieving inclusive and sustainable education, particularly among marginalized students in developing regions. This study examines the impact of digital equity on techno-literacy among marginalized students enrolled in public schools in Sindh, Pakistan. Employing a mixed-methods research design, the study collected quantitative and qualitative data from a sample of 150 students in public schools in Larkana District. Quantitative findings revealed a moderate level of basic digital operational skills among students; however, substantial deficiencies were observed in advanced digital competencies, including problem-solving and critical technology use. Pearson's correlation analysis indicated a significant positive relationship between digital equity and techno-literacy ($r = 0.642$, $p < 0.01$), suggesting that improved access to digital resources, connectivity, and learning opportunities is associated with higher levels of techno-literacy. Qualitative thematic analysis further identified inadequate digital infrastructure, limited internet access, insufficient technological resources, and language barriers as major obstacles to digital inclusion. The study concludes that strengthening digital equity through investments in solar-powered digital infrastructure, localized digital learning resources, and context-sensitive pedagogical frameworks can significantly enhance techno-literacy among marginalized learners, thereby promoting equitable, inclusive, and sustainable educational outcomes in Sindh, Pakistan.

Keywords: Digital Equity, Techno-Literacy, Marginalized Students, Inclusive Education, Sustainable Education

1. INTRODUCTION

In the modern digital era, technology is playing an important role in transforming education by altering how knowledge is accessed, shared and developed. It is widely acknowledged that the integration of ICT has become vital for achieving inclusive and sustainable learning systems (Judge et al., 2004). Whereas Inclusive education and digital equity are fundamental pillars in achieving

SDG 4, its aim is to ensure quality of lifelong opportunities for everyone (Rahma et al., 2025). Although, swift technological advancement, major disparities continuously persist in access to effective use of digital resources, especially among marginalized learner population (Shair et al., 2024). This phenomenon is known as digital divide, which reflects multiple inequalities such as

unequal access to technology caused by geographic location, institutional capacity and socio-economic status (Judge et al., 2004). Therefore, this study focuses on examining the impact of digital equity on techno-literacy among marginalized students in public schools of Sindh. Access to digital devices and internet connectivity is not sufficient for digital equity but it also involves equitable opportunities to use technology effectively, such as access to reliable digital content, meaningful pedagogical integration, and skills to generate and disseminate knowledge (Manglam, 2024). Although many schools have improved digital infrastructure, yet gaps continues to exist in the quality and proper usage of these resources for better outcomes. Especially students from marginalized background frequently experience limited interaction to advanced technological tools; consequently they are engaged in repetitive digital activities which affect their digital competencies (Judge et al., 2004).

In Sindh, Pakistan, these disparities are further deepened by infrastructural gaps, socio-economic limitations and lack of teacher readiness. In current era, day by day digital platforms are becoming essential for education system, consequently it has become crucial to ensure effective utilization of technology and achieving inclusive education in accordance with SDG targets (Karimi, 2025; Falloon, 2020).

Digital divide is influenced by mutually connected factors such as social, technological, ICT infrastructure, digital skills, geographical, economic, and institutional readiness (Manglam, 2024). Additionally, this study also finds that the gaps in access to technological tools and internet connectivity remain a barrier for equitable educational participation, particularly in the marginalized and rural contexts. Consequently, these first-level divides become worsen by the second-level divides, which mainly involves disparities in digital competencies and technological proficiency to use technology for learning purpose effectively (Karimi, 2025).

Poor access to internet, unreliable electricity and poor digital devices weakens the effectiveness of ICT infrastructure, limiting students' engagement

in digital learning environments (Karimi, 2025). This study emphasize that efficacy of digital technology to improve learning outcomes of students remains underutilized in the absence of adequate infrastructure.

Further, successful technology integration in educational learning environment depends on the teachers' digital competences. Technical skills alone are not sufficient for effective use of digital tools but it also requires pedagogical knowledge and potential to design effective learning experiences using digital technology.

In current digital era, the concept of digital competence has expanded from only knowing how to use computers and technology to higher level of thinking skills, effective use of technology, ethical, and understanding socio-cultural aspects of technology (Pettersson, 2017). Further this study highlights that digital technology has evolved rapidly over time and it has become significant for everyday teaching as well. Consequently, teachers are expected to have integrated competencies that enable them to move beyond old-traditional methods to use technology effectively. However, many education systems particularly in public schools of Sindh, Pakistan mostly emphasize on foundational technology competencies while neglecting the multi-dimensional development of digital competencies necessary for meaningful learning (Falloon, 2020). Moreover, research has suggested that leadership, policy frameworks and institutional support positively influence digital inclusion. Strategic planning, and strong leadership in the schools promotes equitable learning environment through efficiently allocating digital resources and promoting professional development of teachers (Karimi, 2025).

Despite rigorous researches on the digital literacy and digital divide, yet existing literature continues to reveal several unresolved gaps. Initially, many previous studies emphasize on technological access, frequently neglecting effective use of technology, such as qualities of digital-based engagement and its influences on learning outcomes of students (Judge et al., 2004). Furthermore, there is lack of empirical evidence

which examine the impact of digital equity primarily on techno-literacy, particularly in developing regions like the marginalized educational settings such as Sindh, Pakistan.

Additionally, past researches mostly focused on digital infrastructure and teacher competence, limited studies adopted holistic approach that examines these variables and their integrated influence on students' learning outcomes (Karimi, 2025; Falloon, 2020). The relationship between infrastructures, digital competencies of teacher, and digital access remain under-research, especially among marginalized students in the public schools of Sindh, Pakistan.

Furthermore, there is shortage of contextual research focusing on the developing region of Sindh, Pakistan, where multi-dimensional issues including social, economic disparities, contextual, infrastructural limitations generate obstacles for digital inclusions. While past studies mainly highlight similar challenges in different context which limit feasibility to local educational environment (Karimi, 2025; Falloon, 2020).

Lastly, a considerable methodological gap exists, as majority of studies have employed either qualitative approaches or quantitative approaches limiting the use of mix-method research design that limit to provide comprehensible insights of the issue. Consequently, this study address this methodological gap by applying mix-method approach to examine the impact of digital on techno-literacy, offering empirical evidence and contextual insights into the challenges faced by marginalized students in Sindh, Pakistan (Karimi, 2025; Judge et al., 2004).

This study is significant as it focus on examining the impact of digital equity on techno-literacy among marginalized students in the public schools of Sindh. Since digital technology has become central of education, techno-literacy has transformed from optional skill to a fundamental skill necessary for participation in the modern knowledge and academic success (Karimi, 2025; Falloon, 2020)

By investigating the association between infrastructure, digital access, students' digital literacy and teacher digital competencies, this

study make a significant contribution to emerging body of knowledge on inclusive and sustainable education. Further this study provides important contributions and insights for educators, stakeholders, and policymakers by highlighting key aspects that impede equitable digital learning opportunities. Moreover, this study emphasizes on effective strategies that address skilled-based development, systematic inequalities, and pedagogical practices rather than just relying access based interventions.

This research is particularly contributing to similar context under the developing regions like Sindh, where digital inequalities continuously limiting educational outcomes. It is essential to tackle these challenges to achieve inclusive education and assure that students, despite of their socio-economic background, can benefit from technological advancements.

1.1 Research Objectives

- To assess the level of digital literacy among students in public schools of Sindh.
- To examine the influence of access to digital resources on students' digital learning skills.
- To identify the institutional and socio-economic factors affecting digital equity in public schools of Sindh.

1.2 Research Questions

- What is the level of digital literacy among students in public schools of Sindh?
- How does access to digital resources influence students' digital learning skills?
- What institutional and socio-economic factors affect digital equity in Sindh schools?

2. Literature review

2.1 Digital Transformation and Educational Inequality

Digital technologies have revolutionized the education system around the world in a short period of time, changing the way knowledge is sought, shared and created. But this change is not the same for everyone. Digital tools have enhanced the flexibility and accessibility of information, but have also uncovered inequalities, especially for

marginalized students. These inequalities are often presented in terms of digital divide – the gap in access to digital technologies between certain social groups.

Previous studies primarily focused on the digital divide as a physical access to devices and internet connection. But later research suggests that this perspective is limited. It is important to highlight the digital inequality as a phenomenon which happens at different levels, such as access, skills, and outcomes as mentioned by scholars like Calderón Gómez (2021). Likewise, says that differences are related to each other and are influenced by socioeconomic status, geographic location, and institutional readiness. With this change in thinking, the concept of digital equity has evolved.

2.2 Concept and Dimensions of Digital Equity

Digital equity is not just about access to technology or Internet; it's about how everyone can put technology to meaningful use for learning and socialization. Willems et al. (2019) argue that digital equity in learning is more than just access; it's the ability to participate, engage, and benefit from learning digitally. This is in line with your research finding that infrastructure, teachers' capacity and learning opportunities are all part of digital inclusion. Recent research also broke digital equity down into several components. The first level pertains to access to devices and to connectivity, and the second level concerns digital skills and competencies. A third and less commonly recognized aspect is technologies' outcomes, including academic achievement and engagement (Calderón Gómez, 2021). In the developing regions these layers become more important because they are not easily used even if they are available.

2.3 Techno-Literacy in the Digital Era

The use of technology in reading, writing, and other literacies has emerged as a major competency in today's educational systems. It extends beyond the use of basic computer technology to a critical evaluation of information, effective communication skills and, creation of

digital content. Digital literacy is defined by Chan et al. (2017) as having an understanding and the ability to use information in several different formats with an emphasis on cognitive and critical skills above technical skills.

With the appearance of the new concept of Society 5.0, techno-literacy becomes even more important because a digital environment is increasingly linked to a physical environment. Asad and Nazir's (2025) study proves that digital equity directly affects the shaping of the techno-literacy of marginalized students, and their greater access to digital devices brings better engagement and skill acquisition. Their results indicate that acquiring techno-literacy is not a process that happens in isolation, but it is a process that is greatly shaped by access to support system and resources.

2.4 Socioeconomic Barriers and the Digital Divide

Socioeconomic status is one of the most frequently mentioned factors in the literature. Students in disadvantaged households are likely to experience a variety of barriers such as having fewer devices, less internet access, and less digital tool exposure. Financial limitation is cited as a key determinant of digital inequality by Hernandez (2023) and income inequality, as found by Li et al. (2023), for internet access. The context of Pakistan is very much evident in these challenges as the marginalized students are dependent on shared devices and unstable connection. According to your research information, lack of financial means is a huge factor in children's access to digital learning. Likewise, it has been highlighted that many students in Sindh do not have access to the basic technological means and that it has a direct impact on the development of their techno-literacy.

2.5 Infrastructure & institutional constraints

Infrastructure is an essential element to digital equity. To effectively integrate technology, reliable Internet, electricity and functional digital devices are essential. But, in many developing areas, these fundamental needs are not consistently met.

According to World Bank (2022) connectivity gaps are still a significant problem in the developing countries, especially in rural areas. Moreover, the lack of adequate ICT infrastructure in Pakistan is still playing a role in restraining digital inclusion initiatives, as highlighted by Shair et al. (2022). Your study also backs this up, which states that inadequate infrastructure in the education system of the province of Sindh is a major hindrance in using the digital technologies in effective ways. Even with good intentions, digital policies don't result in positive outcomes without infrastructure. This indicates that digital equity is not a technology problem, but the problem of systems.

2.6 Teacher Competence and Pedagogical Integration

Another major topic in the literature is on the role of teacher in fostering digital learning. Technological innovation cannot enhance learning outcomes if it is not implemented in a way that helps to understand how to use it. Technology cannot be effective in helping learning outcomes if it is not integrated into teaching in an effective way. Digital competence has two aspects, (1) pedagogical aspects, (2) technical aspects, and (3) ethical aspects; teachers need to go beyond merely using digital tools to being able to apply them meaningfully (Pettersson, 2018).

In many public education systems, however, teachers do not have enough training in digital pedagogy. This restricts their ability to teach their students techno-literacy skills. As mentioned in your working paper, teacher readiness is still a big problem in Sindh since there are not many opportunities to develop the teachers. There are also research findings that indicate that teacher competence is directly correlated with student outcomes. Students are more likely to learn at a higher level and be active if teachers are confident in using technology.

2.7 Awareness, Culture and social factors

Social and cultural aspects influence digital engagement, in addition to infrastructure and

skills. In most underprivileged communities, there is limited knowledge of the educational benefits of technology. Parents might use digital technologies more for entertainment than learning outcomes, lowering their support of students' digital activities.

In their recent study, Wu and Peng (2024) emphasize how awareness is key for digital inclusion, especially in rural and marginalized communities. In the same way, van der Vlies (2020) points out the need for parental support and policy awareness for digital learning.

This research indicates that digital equity needs to go beyond technological and institutional solutions and involve a shift in perceptions and attitudes about technology.

2.8 Policy and Strategic Interventions

There are several governmental and institutional policies aimed at solving digital inequality. There are a number of programs, like ICT integration programs and national digital strategies, which strive to enhance access and digital literacy. In Pakistan, initiatives such as the Digital Pakistan Vision have been aimed at both developing the infrastructure and improving the digital skills. But it has been found that the implementation of this policy can have problems of coordination, funding and adaptation to context. Aziz (2020) states that policies need to be flexible and culturally responsive in meeting the needs of communities. A combination of infrastructure, teacher training, and community involvement are essential elements for effective strategies.

2.9 Identified Research Gap

Although a number of publications have been released, there are a few gaps. Many studies are only interested in access to technology, and very little research has been conducted on the use of technology for learning. Also, much of the existing research focuses exclusively on an individual dimension – infrastructure or teacher competence – and does not give any weight to the joint effect of both.

However, in Pakistan, as regards Sindh, there is a clear absence of empirical studies that have

investigated the concept of digital equity and techno-literacy as a whole, especially with mixed methods. As you mentioned in your study, much of the current research is not a good fit for the context and does not reflect the complexity of marginalized students. Hence, this study is designed for filling the above gaps and to provide a detailed analysis of impact of digital equity on techno-literacy in public schools of Sindh

3. Research Methodology

This chapter explained the complete methodological framework adopted for this study. It described the research design, sampling techniques, population, data collection methods, research instruments, data analysis procedures, ethical consideration, validity strategies and trustworthiness. The methodology was carefully structured to align with study objectives and to ensure comprehensive mixed-method inquiry. This study sought to examine the impact of Digital Equity on the Techno-Literacy among marginalized students in selected public schools of Larkana District for Inclusive and sustainable Education, while also examined the challenges and barriers they experienced.

3.1 Philosophical Stance

This research used a mix-method approach which is directly aligned with the philosophical stance of the pragmatism. Pragmatism focuses on the

practical ideas, sustainable solutions and further it also focuses on addressing the real-world problems. This stance has supported the flexibility by combining both qualitative and quantitative methods to develop complete and comprehensive understanding of the research problem.

3.2 Conceptual Framework

This study is based on the Theory of Digital Equity, which highlights the importance of equitable access to digital skills, resources and opportunities for all learners. Aligned with this theory, current research is based on a Techno-literacy, which reflects competencies of the students to utilize learning tools effectively. These variables help to enhance students' participation, engagement and academic achievement as a whole. As a result, continuous access to technology enhance students' skills which contribute to more inclusive educational practices and long-term sustainability in learning outcomes, particularly for marginalized students, thereby promoting broader objectives of educational equity long-lasting learning success. All of these components considered to be crucial to foster digital equity and to improve techno-literacy, which collectively improve inclusive and sustainable educational outcomes especially for marginalized students of public school Larkana, Sindh.

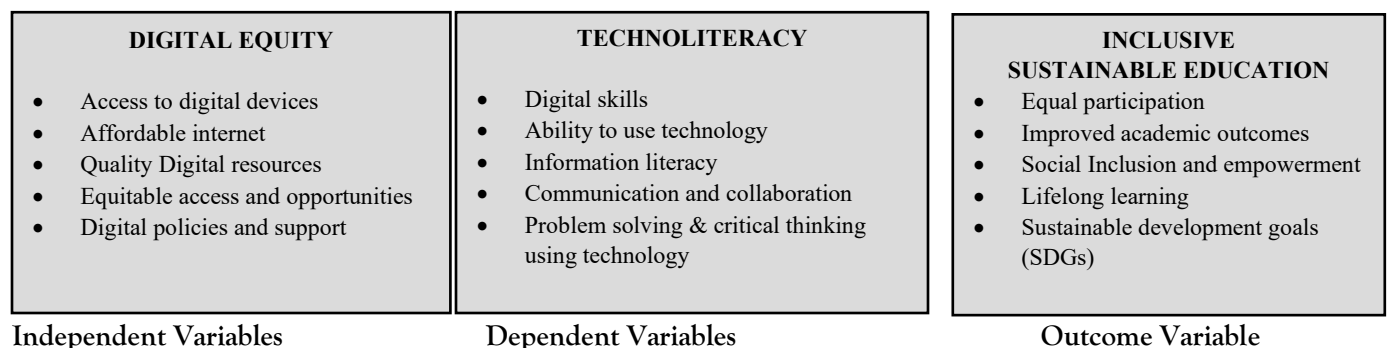


Figure 1: Conceptual Framework

3.3 Research Design

The study employed a Mixed-Methods Research Design similarly to the approach by Creswell et al., (2018). Moreover, it followed the Sequential

Explanatory Design employed by Asad and Nazir (2025). In this approach, the research began with a quantitative phase that measured the level of

digital equity and its effect on techno-literacy skills of marginalized students of selected public schools of Larkana, Sindh. Followed by the qualitative phase, a qualitative phase was conducted using focus group discussions to explore teachers' lived experiences, perceptions, contextual barriers and challenges to promote techno-literacy through equitable access to digital technologies in the marginalized settings. This design facilitates the quantitative results to direct the qualitative inquiry, establishing the complementary relationship between statistical patterns and descriptive narratives.

3.3.1 Quantitative phase (survey)

The population selected for this study included marginalized students enrolled in the public schools of Larkana district. Such students generally belong to underprivileged background, low income-households, or communities with limited access to the digital technologies and resources.

A stratified random sampling technique was used for quantitative investigation to ensure representation of different marginalized groups (rural, urban-slum, low-income, out-of-school learners). This enhances generalizability across diverse contexts. (Creswell & Creswell, 2017). A Quantitative sample of 100 students aged 15-17 years, from grade 9th to intermediate level enrolled in selected public schools. For this purpose, five schools were chosen as a strata (Saint Joseph High School, Girls High School, Government Pilot Higher Secondary school, Government girls' model high EM school and Government Boys high school). From each school, total 20 students were included in a sample based on recommended sample guideline.

3.3.2 Qualitative phase (Focus groups /interviews)

For qualitative investigation convenience sampling method was used for selecting participants for focused group discussions. A group of six teachers from selected public schools were chosen on their willingness and availability to participate. These teachers were invited to take

part in focused group discussion to share their own experiences and perspectives of digital equity and techno-literacy. Semi-structured questions were designed to allow the participants to share their experiences, thoughts freely until the key areas of the research were explored. This format enabled the researchers to examine deeper into participants' responses. The questions were continued until data saturation was achieved (Guest et al., 2020).

3.4 Data collection tools and method

This study has adopted a mixed-methods design, combining quantitative and qualitative data collection to get both measurable outcomes and vast, contextualized experiences.

(i). The quantitative method of this study used close ended questions. Structured questionnaire was used to understand the behavior, opinion, and characteristics of the whole population. Survey design is a quantitative research strategy that enables researchers to collect measurable data of participants' beliefs, opinions, attributes and behaviors. It was divided into three-section, each section contained eight-items of the questions to measure students' perception, ability and learning confidence related to use of digital technology. A five-point Likert scale was used where each item ranged from 1= Strongly Disagree to 5= Strongly Agree. Then data was analyzed statistically to find trends that could address the research issues and assumptions. The reliability of the instrument was examined by conducting pilot test of 10-15 respondents. The Cronbach's alpha was calculated to examine the internal consistency of the items.

(ii). The Qualitative method of this study used a focused group (FGD) interview. Semi-structured questions were designed that allows researchers to explore the in-depth views of participants. The FGD guide was used in this study contained exploratory-questions that provided opportunity to participants to express their experiences, challenges and perceptions related to digital technology.

3.5 Data Collection Procedures and data analysis

The mix-method research design contained both quantitative and qualitative methods. In quantitative phase primary data was collected manually by using printable questionnaires' Forms in collaboration with five different schools (Saint Joseph High School, Girls High School, Government Pilot Higher Secondary school, Government girls' model high EM school and Government Boys high school). The Structured questionnaire employed to collect data to assess the impact of Digital Equity on Techno-Literacy

among marginalized students in Public schools of Sindh for Inclusive and Sustainable Education. Data was analyzed descriptively and inferentially by using SPSS data analyzing software. SPSS software helps with descriptive and correlation analysis to highlight the trends and patterns in collected data. In qualitative phase semi-structured interviews (FDG) were used to gain in-depth insights by using thematic analysis following Braun & Clarke's six-phase model. Interviews were followed by data analysis which included data transcription and data analysis.

4. Quantitative Results and Statistical Analysis

4.1 Participant Demographics

Table 1: Demographic Profile of Respondents (n=150)

Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	78	52%
	Female	72	48%
Education	Secondary	82	54.7%
	Higher Secondary	68	45.3%

Table 1 presents the demographic characteristics of the respondents who participated in this study. The sample consisted of 150 students, with 52% male and 48% female participants, indicating a nearly balanced gender distribution. Regarding educational level, 54.7% of the respondents were enrolled in secondary education, while 45.3% were studying at the higher secondary level. This

balanced representation enhances the credibility of the study by including students from different educational stages and both genders. Consequently, the demographic composition provides an appropriate foundation for examining the relationship between digital equity and techno-literacy among marginalized students in public schools of Sindh

4.2 Item-level Analysis: Techno-Literacy Skills

Table 2: Distribution of student Responses for Digital Skills

Question/Item	1	2	3	4	5
Operate hardware independently.	5	15	30	60	40
Use Google for research	10	25	45	40	30
Use MS word efficiently.	20	40	50	25	15
Identify digital fake news	40	50	35	15	10

Table 2 illustrates students' responses regarding various dimensions of techno-literacy. The

findings indicate that most students possess basic operational digital skills, particularly in operating

hardware independently and conducting simple online searches. However, considerably fewer students demonstrated proficiency in advanced digital competencies, such as efficiently using productivity software and identifying fake or misleading online information. These findings suggest that while marginalized students have

acquired fundamental technological skills, they continue to experience limitations in higher-order digital literacy, including critical thinking, information evaluation, and effective technology utilization, highlighting the need for more comprehensive digital learning opportunities.

4.3 Item-Level Analysis; Digital Access

Table 3: Distribution of Student Response for Digital Access

Question/Item	1	2	3	4	5
Access to personal device at home	45	35	20	30	20
Reliable home internet connection.	55	40	25	20	10
Well-equipped school computer lab.	15	25	30	50	30
Sufficient practice time in lab.	30	45	40	25	10

Table 3 presents students' perceptions regarding access to digital resources. The results reveal that many respondents experience limited access to personal digital devices and reliable internet connectivity at home. Although several schools provide computer laboratory facilities, students reported insufficient opportunities for practical use and limited access to these resources. These

findings indicate that unequal access to technology continues to exist among marginalized students, restricting their opportunities to develop digital competencies. The results emphasize that improving digital infrastructure, internet availability, and practical learning opportunities is essential for promoting equitable access to technology in public schools.

4.4 Correlation Analysis

Table 4: Pearson Correlation between Access and Literacy

****Correlation is significant at the 0.01 (2-tailed).**

	Digital Access	Techno-Literacy
Digital Access	1	0.642**
Techno-Literacy	0.642	1

Table 4 presents the Pearson correlation analysis examining the relationship between digital access and techno-literacy. The analysis revealed a statistically significant positive correlation ($r = 0.642$, $p < 0.01$), indicating a moderately strong relationship between the two variables. This finding suggests that students with greater access to digital devices, internet connectivity, and

learning resources tend to demonstrate higher levels of techno-literacy. The result supports the central objective of the study by confirming that digital equity contributes positively to the development of students' technological competencies and their ability to effectively engage in digital learning environments

5. Qualitative Results: Thematic Analysis

Table 5: Qualitative Themes and Findings

Theme	Core finding
Infrastructure Deficit	Consistent power outages render school labs unusable.
Linguistic Barriers	English-centered software deters Sindhi-medium students.
Gendered Access	Cultural restrictions on technology use for females at home.
Pedagogical Gap	Teachers focus on rote theory rather than practical usage.

Table 5 summarizes the major themes that emerged from the qualitative analysis. Four key challenges were identified: infrastructure deficit, linguistic barriers, gendered access, and pedagogical gaps. Teachers reported that unreliable electricity, inadequate technological facilities, and unstable internet connectivity significantly hinder effective digital learning. Furthermore, language barriers, cultural restrictions affecting female students' technology use, and traditional teaching practices limit students' opportunities to develop advanced techno-literacy skills. These qualitative findings complement the quantitative results by explaining the contextual factors that continue to influence digital equity and educational inclusion among marginalized students in Sindh.

6. Discussion:

Interpretation of Results

The findings of this study provide strong evidence that digital equity significantly influences the development of techno-literacy among marginalized students in public schools of Sindh, Pakistan. By integrating both quantitative and qualitative findings, the study offers a comprehensive understanding of the challenges and opportunities associated with digital learning in disadvantaged educational settings. Overall, the results indicate that although students possess basic technological skills, considerable inequalities in access to digital resources, infrastructure, and instructional support continue to hinder the development of advanced techno-literacy. These findings directly address the research objectives and demonstrate that achieving inclusive and sustainable education requires more than simply

providing technological devices; it requires equitable opportunities to access, utilize, and benefit from digital technologies.

The quantitative findings reveal that students generally possess moderate levels of techno-literacy. Most respondents reported confidence in performing basic technological operations, such as operating digital devices and conducting simple online searches. However, their ability to perform higher-order digital tasks, including evaluating online information, identifying fake news, efficiently using productivity software, and applying technology for problem-solving, remained comparatively limited. This pattern indicates that students have developed operational digital skills but have not yet acquired the advanced competencies necessary for effective participation in modern digital learning environments. These findings suggest that the existing educational practices primarily emphasize basic computer usage rather than fostering critical thinking, digital communication, information literacy, and creative application of technology. Consequently, students remain competent users of technology at a basic level but are less prepared to utilize digital technologies for independent learning and knowledge creation.

The findings concerning digital access further explain these differences in techno-literacy. Many respondents reported limited access to personal digital devices, unstable internet connectivity, and inadequate opportunities to practice digital skills both at home and within school environments. Although several schools possessed computer laboratories, students indicated that laboratory access was often limited and insufficient for meaningful skill development. These findings

demonstrate that digital equity remains unevenly distributed among marginalized students. Access to technology continues to depend upon socio-economic conditions, institutional resources, and geographical circumstances. Therefore, unequal access to digital infrastructure directly restricts students' opportunities to strengthen their technological competencies and participate fully in digital learning experiences.

One of the most significant findings of this study is the statistically significant positive relationship between digital equity and techno-literacy. The Pearson correlation coefficient ($r = 0.642$, $p < 0.01$) indicates a moderately strong positive association between these two variables. This result suggests that improvements in digital equity are associated with corresponding improvements in students' techno-literacy. Students who have better access to digital devices, internet connectivity, quality learning resources, and supportive educational environments demonstrate stronger technological competencies than students experiencing limited access. Although correlation analysis does not establish causality, the strength of the relationship provides convincing empirical evidence that digital equity is an important determinant of techno-literacy among marginalized students. This finding supports the central assumption of the study that equitable access to digital resources contributes significantly to students' technological development and educational participation.

The qualitative findings provide valuable contextual explanations for these statistical relationships. Teachers consistently identified inadequate digital infrastructure as one of the greatest barriers to effective technology integration. Frequent electricity outages, unreliable internet services, outdated computer equipment, and poorly maintained laboratories limit students' opportunities to practice and apply digital skills. These infrastructural deficiencies reduce the effectiveness of technology-based teaching and make it difficult for schools to create consistent digital learning environments. Consequently, even motivated students experience interruptions that restrict the

continuous development of techno-literacy. These qualitative findings reinforce the quantitative evidence demonstrating that digital access remains a fundamental prerequisite for meaningful technological learning.

Another important theme emerging from the qualitative analysis relates to linguistic barriers. Teachers explained that many educational software applications, digital platforms, and instructional resources are available primarily in English, whereas many students in Sindh receive instruction through Sindhi or Urdu. This language mismatch reduces students' confidence when interacting with digital technologies and limits their ability to explore educational resources independently. The findings therefore indicate that digital equity extends beyond physical access to technology and includes equitable access to culturally and linguistically appropriate learning materials. Without localized digital resources, many marginalized students remain disadvantaged despite having occasional access to technological devices.

Gender-related inequalities also emerged during the qualitative investigation. Participants reported that cultural expectations and household practices often restrict female students' opportunities to use digital devices outside school. Although schools attempt to provide equal educational opportunities, differences in home environments continue to influence students' digital experiences. Female students may therefore receive fewer opportunities to practice technological skills, limiting their confidence and overall techno-literacy. These findings suggest that achieving digital equity requires educational policies that address broader social and cultural factors influencing technology access and participation.

The qualitative findings additionally identified a considerable pedagogical gap within public schools. Teachers acknowledged that classroom instruction frequently emphasizes theoretical knowledge and examination preparation rather than practical application of technology. Students receive limited opportunities to engage in collaborative learning, digital problem-solving, content creation, and critical evaluation of online

information. As a result, students develop operational familiarity with technology but remain unable to apply digital tools for higher-order learning activities. This finding explains the relatively lower performance observed in advanced techno-literacy skills and highlights the importance of strengthening teachers' digital pedagogical competencies alongside investments in technological infrastructure.

The findings of this study are consistent with previous research emphasizing that digital equity represents a multidimensional concept involving access, opportunity, competence, and meaningful participation. The results support earlier studies that argue equal distribution of technological devices alone cannot eliminate the digital divide. Instead, sustainable improvements in techno-literacy require reliable infrastructure, effective teacher training, equitable internet access, localized digital learning resources, and supportive institutional policies. The integration of quantitative and qualitative evidence demonstrates that these dimensions are closely interconnected and collectively determine students' ability to benefit from digital education. Overall, this study successfully addresses its research objectives by demonstrating that techno-literacy among marginalized students remains moderate, that digital access significantly influences students' technological competencies, and that institutional, socio-economic, infrastructural, linguistic, and pedagogical factors collectively shape digital equity in public schools of Sindh. These findings support the principles of Digital Equity Theory by confirming that meaningful participation in digital education depends upon equitable opportunities rather than simple availability of technology. Therefore, strengthening digital equity through improved infrastructure, reliable internet connectivity, localized educational resources, continuous teacher professional development, and inclusive educational policies can substantially enhance techno-literacy among marginalized learners. Such improvements will contribute not only to better educational outcomes but also to the broader goals of inclusive and sustainable education by ensuring

that every student, regardless of socio-economic background or geographical location, has an equal opportunity to participate effectively in the digital world.

7. Conclusion, implication and future Direction

In Sindh, digital equity is currently unevenly distributed and it is also inconsistent. Therefore future policies must prioritize localized curriculum, solar-powered labs, and the focus of teacher training should be on digital problem solving rather than rote memorization which is traditional method commonly used in public schools of Sindh

Building upon these findings, the present study demonstrates that digital equity extends beyond the mere provision of computers or internet connectivity. Instead, it represents a multidimensional concept encompassing equitable access to digital devices, reliable internet connectivity, quality digital learning resources, competent teachers, supportive educational policies, and opportunities for meaningful engagement with technology. The quantitative findings established a significant positive relationship between digital equity and techno-literacy, indicating that students who experience greater digital access and learning opportunities are more likely to develop stronger technological competencies. The qualitative findings further reinforced these statistical results by revealing that infrastructural deficiencies, unreliable electricity, inadequate technological resources, language barriers, and traditional pedagogical practices continue to restrict meaningful digital participation among marginalized learners in public schools of Sindh.

The findings collectively indicate that improving digital infrastructure alone cannot eliminate educational inequalities. Sustainable improvements in techno-literacy require a comprehensive educational ecosystem where infrastructure, curriculum, teacher competence, institutional support, and community participation function together. The mixed-method findings therefore provide empirical

evidence that digital equity should be considered an educational right rather than merely a technological intervention. Ensuring equitable digital opportunities enables marginalized students to participate more effectively in contemporary learning environments and contributes directly to inclusive and sustainable education.

Practical Implications

The findings of this study have significant practical implications for educational institutions, teachers, school administrators, policymakers, curriculum developers, and development partners working toward educational improvement in Pakistan.

For policymakers, the study highlights the urgent need to formulate comprehensive digital equity policies that extend beyond the distribution of technological devices. National and provincial governments should prioritize long-term investments in digital infrastructure, particularly in rural and marginalized communities where access remains highly uneven. Reliable electricity, affordable broadband connectivity, functional computer laboratories, and regular maintenance mechanisms should be integrated into educational development plans. Investment in renewable energy solutions, including solar-powered digital laboratories, may provide sustainable alternatives for schools experiencing frequent electricity interruptions.

For educational institutions, the findings suggest that schools should establish technology-rich learning environments where digital resources are integrated into everyday classroom instruction rather than being confined to isolated computer laboratories. School improvement plans should include continuous monitoring of digital resource utilization, equitable student access, and periodic evaluation of technology-supported teaching practices.

Teachers play a central role in translating digital resources into meaningful learning experiences. Therefore, teacher professional development programs should focus not only on technical proficiency but also on digital pedagogy, problem-solving approaches, critical thinking, collaborative

learning, and responsible technology use. Continuous professional learning communities should be established to enable teachers to exchange effective digital teaching practices and remain updated with emerging educational technologies.

Curriculum developers should revise existing curricula to integrate techno-literacy competencies across all subject areas instead of treating digital education as an isolated discipline. Students should be provided with opportunities to develop information literacy, digital communication skills, online collaboration, computational thinking, digital citizenship, ethical technology use, and critical evaluation of online information. Such curriculum integration will better prepare learners for participation in knowledge-based societies.

Parents and local communities also have an important role in strengthening digital inclusion. Community awareness programs should encourage families to support educational uses of technology while promoting responsible and safe digital practices at home. Collaboration among schools, parents, local government authorities, and community organizations can substantially improve the sustainability of digital inclusion initiatives.

Theoretical Implications

This study contributes to the growing body of literature on Digital Equity Theory by providing empirical evidence from a developing-country context where digital inequalities remain deeply influenced by socioeconomic, infrastructural, and institutional challenges. The findings support the proposition that digital equity should be conceptualized as a multidimensional construct involving access, opportunity, competence, and meaningful educational participation.

Furthermore, the study extends existing discussions on techno-literacy by demonstrating that students' technological competencies develop through continuous interaction with supportive educational environments rather than through access to technology alone. The mixed-method findings therefore reinforce contemporary perspectives suggesting that digital inclusion

requires the integration of technological infrastructure, pedagogical effectiveness, institutional readiness, and equitable learning opportunities.

The study also contributes to the broader discourse on Sustainable Development Goal 4 by illustrating how digital equity can serve as an enabling mechanism for achieving inclusive and equitable quality education. Strengthening techno-literacy among marginalized learners not only enhances academic achievement but also promotes lifelong learning, social participation, and future employability.

Study Limitations

Despite its valuable contributions, the present study has several limitations that should be considered while interpreting the findings. First, the quantitative sample was limited to selected public schools in Larkana District; therefore, the findings may not fully represent all districts of Sindh or other provinces of Pakistan. Second, the qualitative investigation involved a relatively small number of participants through focus group discussions. Although data saturation was achieved, broader stakeholder participation—including school leaders, parents, education officers, and policymakers—could provide additional insights into digital equity challenges. Third, the study adopted a cross-sectional research design that examined digital equity at a single point in time. Longitudinal investigations may provide a deeper understanding of how digital competencies develop over time following policy interventions or technological improvements. Finally, the study focused primarily on public schools; future comparisons involving private schools and other educational settings may generate broader evidence regarding educational inequalities.

Recommendations for Future Research

Future researchers should extend this investigation by conducting large-scale studies involving multiple districts and provinces across Pakistan to improve the generalizability of findings. Comparative studies between rural and

urban schools, public and private institutions, and different socioeconomic groups would further enhance understanding of contextual variations in digital equity.

Future studies may also employ longitudinal research designs to evaluate the long-term impact of digital equity initiatives on students' techno-literacy, academic achievement, and lifelong learning outcomes. Experimental and intervention-based research examining the effectiveness of teacher training programs, localized digital curricula, artificial intelligence-supported learning systems, and technology-assisted instructional strategies would provide valuable evidence for educational decision-makers. Researchers are further encouraged to investigate additional variables that may influence techno-literacy, including digital motivation, parental involvement, school leadership, digital resilience, self-efficacy, online safety awareness, and students' digital well-being. Mixed-method and multidisciplinary approaches should continue to be employed because they provide comprehensive understanding by integrating statistical evidence with contextual experiences.

Future investigations should also examine emerging educational technologies—including artificial intelligence, adaptive learning platforms, virtual laboratories, augmented reality, and immersive digital environments—to determine how these innovations can promote equitable learning opportunities among marginalized populations. Such research will assist governments and educational institutions in developing evidence-based digital education policies aligned with rapidly evolving technological landscapes.

Overall, the findings of this study emphasize that achieving digital equity is fundamental for developing techno-literacy and advancing inclusive and sustainable education. Addressing infrastructural inequalities, strengthening teacher competence, integrating digital competencies within curricula, and implementing context-sensitive educational policies can substantially improve learning opportunities for marginalized students. By adopting comprehensive and equitable digital education strategies, educational

systems in Sindh and similar developing regions can move closer toward realizing Sustainable Development Goal 4 and ensuring that every learner has an equal opportunity to participate successfully in an increasingly digital world

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