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## Innovative technologies and their impact on achieving quality education (SDG 4)

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### Abstract

This study aims to explore how technology contributes to achieving SDG 4 education quality in Pakistani schools through equitable and inclusive educational practices. An investigation based on qualitative data from focus group discussions with 15 individual teachers in Pakistani high schools from Punjab was carried out. A self-administered survey was conducted to obtain data from school teachers. The study employed simple random sampling for participant selection, and data were analyzed through NVivo. Findings indicate that technology promotes equal access to education, inclusive practices for diverse learners, active and collaborative learning, and the reduction of sociocultural and linguistic barriers. However, infrastructural constraints, a lack of proper training for teachers, and low levels of engagement are some of the challenges. The importance of this study is that, in integrating technology, it has to be done in a manner that aligns with constructivism, sociocultural theory, and Universal Design for Learning for education to be inclusive, accessible, and of quality. Other recommendations for policymakers and educators concern investing in infrastructure, expanding teacher development programs, and developing and implementing equitable technology policies. This study focused exclusively on high schools within Pakistan. Additionally, this study is also limited by its reliance on a research framework deduced from previous foundations and literature. The novelty of this article lies in the fact that it addresses the gap in existing literature by exploring how technology contributes to achieving SDG 4 education quality in Pakistani schools through equitable and inclusive educational practices.

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**Transparency:** The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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## **1. Introduction**

Sustainable Development Goal 4 (SDG 4) Quality Education for All emphasizes the importance of equity in access to quality education that promotes lifelong learning. This goal is crucial for breaking the cycle of poverty, fostering economic growth, and empowering individuals with the knowledge and skills needed to contribute to society. Also, satisfaction is based on the quality of education rendered by organizations [1]. In this context, the integration of emerging technologies in education has become increasingly significant since it has the potential to bridge gaps in access, participation, and achievement. Innovative tools such as AI, blockchain, and digital games have been consistently reported to enhance learning experiences, making education more engaging and accessible for diverse learners. These technologies can provide personalized learning paths, support for students with special needs, and opportunities for marginalized groups to gain skills and knowledge that were previously out of reach.

Education quality is largely defined by its capacity to prepare students for the challenges posed by a fast-changing world. In the past, educational assessments primarily focused on traditional factors such as curriculum content, instructional methods, and resource availability. However, with the ongoing changes in the global educational landscape, emerging technologies have become crucial in transforming how education is delivered, experienced, and evaluated. The integration of technologies such as artificial intelligence (AI), machine learning (ML), virtual reality (VR), and cloud computing has not only enhanced academic outcomes but also opened up new opportunities for personalized learning, broader accessibility, and global collaboration [2].

Technologies such as AI and ML are transforming the personalization of education. These tools analyze student data to deliver adaptive learning pathways and immediate feedback, facilitating a more individualized learning journey [3]. Similarly, VR is reshaping education by offering immersive environments in which students can engage in interactive and practical learning experiences that would be impossible in traditional classrooms [4]. Furthermore, the use of cloud-based platforms and mobile technology has made learning more flexible, enabling students to access educational content at their convenience and overcoming barriers to access, particularly for marginalized groups [5].

Big data and learning analytics have become pivotal in enhancing educational quality. By processing extensive student performance data, these technologies allow educators to uncover learning trends, predict academic success, and provide targeted interventions [6]. They facilitate a more analytical, data-driven approach to refining teaching techniques and improving educational outcomes. However, the broad-scale implementation of these technologies still faces challenges related to infrastructure, teacher training, and digital access equity [7]. While emerging technologies hold immense promise for improving educational quality, their integration must be thoughtfully managed to address these issues and ensure equitable educational experiences for all learners.

With the growing integration of emerging technologies into educational systems, it is important to evaluate their impact on the overall quality of education. These technologies have the potential to revolutionize educational practices by offering personalized learning experiences, increasing student engagement, and improving learning outcomes [3, 4]. However, challenges related to their effective implementation across diverse educational contexts remain insufficiently explored. Notably, there is limited research on how these technologies influence the accessibility and fairness of educational opportunities, particularly for underserved populations [7]. Additionally, while technology tools promise more individualized learning experiences, there is uncertainty regarding their long-term impact on students' cognitive and social development and whether they can achieve sustained improvements in educational outcomes [2]. The impact of data-driven tools, such as learning analytics, on identifying learning gaps and fostering student success is not yet fully understood [6].

This study aims to explore the role of technology in achieving SDG 4 by examining how digital tools contribute to equitable and inclusive educational practices [8]. The research will investigate how technology can be leveraged to improve educational outcomes for all, including those from underrepresented and marginalized communities. The main research questions to be addressed through Focus Group Discussions (FGD) relate to the impact of emerging technologies on educational access and participation for marginalized groups, the barriers and facilitators to the effective use of technology in education, and ways to design and implement technology to support inclusive educational practices in Pakistani high schools. This research innovatively examines how emerging technologies can bridge the digital divide and ensure inclusive quality education in Pakistan, aligning with SDG 4. It explores the practical integration of emerging technologies in Pakistani schools, offering fresh insights into technology's role in educational equity through governmental actions and policies [9].

This study is expected to shed light on the impact of technology on marginalized and underrepresented groups, informing policy and practice to ensure that educational technologies contribute to a more equitable and inclusive global education system. Understanding these dynamics is vital for realizing the vision of SDG 4, where quality education is accessible to all, regardless of location, background, or circumstances.

## **2. Literature Review**

### **2.1. Constructivism**

The theory of constructivism posits that learning is an active process where students construct knowledge through direct interaction with their environment, and this is particularly relevant in the context of emerging technologies in education [10]. In today's educational landscape, technologies like AI, ML, VR, and interactive e-learning platforms provide rich opportunities for students to engage in active, personalized learning experiences. These technologies foster individualized learning pathways by adapting content to meet the specific needs and progress of each student, supporting deeper engagement and motivation [3]. VR and simulations, for example, allow students to engage in hands-on, immersive learning experiences that enable them to actively build knowledge in ways that traditional classrooms cannot offer [4].

Furthermore, the integration of multimedia learning environments, as highlighted by Mayer [5], supports cognitive processing by combining visual, auditory, and interactive elements, catering to diverse learning styles. These tools not only facilitate the construction of knowledge but also enhance collaboration through digital platforms, where students can engage in problem-solving and share ideas, thus enriching the learning experience. By aligning with constructivist principles, emerging technologies provide powerful mechanisms for enhancing education quality, ensuring more engaging, inclusive, and adaptive learning environments that are essential for the development of 21st-century skills.

## *2.2. Socio-Cultural Theory*

Vygotsky's [10] sociocultural theory underscores the importance of social interaction and cultural context in cognitive development, suggesting that learning occurs through meaningful collaboration and the use of tools within a cultural framework [10]. In the context of emerging technologies, this theory is highly relevant, as technologies like online learning platforms, social media, and collaborative tools enable students from diverse socio-cultural backgrounds to engage in joint problem-solving and peer interaction, which are central to Vygotsky's [10] concept of the zone of proximal development (ZPD) [11]. These technologies facilitate collaborative learning, allowing students to scaffold each other's knowledge and skills, with guidance from teachers or more knowledgeable peers, in a socially mediated environment [6]. For instance, AI-driven platforms can help identify the specific needs of learners and create adaptive learning pathways, while also offering real-time feedback, enabling both the learner and educator to engage in an iterative process of growth.

Additionally, technologies such as Virtual Reality (VR) and Augmented Reality (AR) provide immersive, context-rich environments where learners can practice and reinforce cognitive and social skills in simulated, yet realistic settings [4]. Through these tools, education becomes more inclusive, allowing students from diverse backgrounds to access and engage with content that is culturally relevant and contextually appropriate, further enhancing educational quality. By aligning with Vygotsky's emphasis on the mediation of cognitive development through social and cultural tools, these emerging technologies offer opportunities to expand the reach and impact of education across varied socio-cultural contexts.

## *2.3. Universal Design of Learning (UDL)*

Universal Design for Learning (UDL) emphasizes creating flexible learning environments that cater to the diverse needs, preferences, and abilities of all learners. UDL principles are particularly enhanced by emerging technologies, as these tools can offer a variety of ways to present information, engage students, and allow for different forms of expression [12]. For example, multimedia resources such as videos, podcasts, and interactive graphics allow students to access content in multiple formats, addressing diverse learning preferences and enhancing comprehension [5].

Technologies like AI-driven adaptive learning platforms provide personalized learning pathways, adjusting content and assessments in real-time to match each learner's individual progress, thus supporting students at different levels of proficiency [3]. VR and AR offer immersive, hands-on experiences that can engage students in practical learning, making abstract concepts more tangible, and fostering greater engagement and motivation [4]. Moreover, tools for collaboration, such as online discussion forums and shared workspaces, facilitate diverse modes of expression and communication, promoting interaction and social learning, which are critical for inclusivity [2]. Through these technological advancements, UDL fosters equitable access by ensuring that students, regardless of their ability or socio-cultural background, have the opportunity to engage with the curriculum in meaningful ways, thereby improving educational quality and outcomes for all learners.

## *2.4. Seamless Learning Design*

Seamless Learning Design (SLD) emphasizes the integration of learning across both formal and informal settings, enabling continuous learning experiences that transcend traditional classroom boundaries. Emerging technologies, such as mobile apps, learning management systems (LMS), and cloud-based platforms, are central to facilitating this integration, as they provide learners with access to educational resources anytime and anywhere, thus fostering lifelong learning [13]. Mobile apps, for example, enable learners to access educational content on the go, promoting learning beyond the classroom and reducing barriers for students who may face challenges related to time, location, or resources. These technologies not only support learning in diverse contexts but also enable personalized, adaptive learning experiences through data-driven insights and AI algorithms, catering to individual needs and preferences [3].

Furthermore, technologies such as social media and collaborative tools enable informal learning opportunities, where students can engage with peers, participate in discussions, and share knowledge, contributing to a more holistic educational experience [6]. SLD's integration of technology in education has made significant contributions to improving equity by reaching underserved groups who may not have access to traditional educational resources, thereby promoting inclusive learning. This approach enhances access to educational opportunities for marginalized communities, ultimately improving educational quality by fostering more flexible, personalized, and inclusive learning environments.

# **3. Methodology**

## *3.1. Research Design, Population and Sampling*

This study will use a qualitative research design to investigate the impact of technology on promoting equity and inclusiveness in education. This method has been chosen because it employs an inductive approach, focusing on individual meaning, facilitating an in-depth understanding of experiences and perspectives, and emphasizing the importance of reporting the complexity of a situation [14].

A total of 15 individuals participated in the study, representing high schools across various regions of Punjab, Pakistan. They were selected through purposive sampling, focusing on teachers with a minimum of 3 years of experience in teaching high school students. Care was taken to include respondents with diverse backgrounds, gender distribution, education levels, and geographical locations to ensure diversity. The research employed a Focus Group Discussion (FGD) format to gather insights from the participants about the research topics under study.

The participants were divided into three groups with five members each: Group 1 consisted of teachers from a male community school; Group 2 was formed with teachers from a female public school; and Group 3 comprised teachers from a mixed-gender private school. Table 1, 2, and 3 provide a visual representation of the participants' demographic details:

**Table 1.**  
*Demographic Details, Group 1 (Male School).*

| Participants | Gender | Education Level | Years of Experience | Subject Teaching |
|--------------|--------|-----------------|---------------------|------------------|
| 1            | Male   | Bachelor's      | 15                  | Chemistry        |
| 2            | Male   | M.Phil          | 13                  | Chemistry        |
| 3            | Male   | Undergraduate   | 7                   | Mathematics      |
| 4            | Male   | M.Phil          | 12                  | English          |
| 5            | Male   | Master's        | 23                  | Economics        |

**Table 2.**  
*Demographic Details, Group 2 (Female School).*

| Participants | Gender | Education Level | Years of Experience | Subject Teaching |
|--------------|--------|-----------------|---------------------|------------------|
| 1            | Female | M.Phil          | 10                  | English          |
| 2            | Female | Master's        | 18                  | Biology          |
| 3            | Female | D.Pharmacy      | 12                  | Biology          |
| 4            | Female | Master's        | 8                   | Chemistry        |
| 5            | Female | Master's        | 11                  | Physics          |

**Table 3.**  
*Demographic Details, Group 3 (Mixed-Gender School).*

| Participants | Gender | Education Level | Years of Experience | Subject Teaching |
|--------------|--------|-----------------|---------------------|------------------|
| 1            | Male   | Bachelor's      | 14                  | Chemistry        |
| 2            | Female | Master's        | 17                  | Economics        |
| 3            | Female | Master's        | 10                  | Biology          |
| 4            | Male   | Masters         | 19                  | Physics          |
| 5            | Male   | Master's        | 7                   | Physics          |

### 3.2. Instrumentation

A total of 16 questions were used to gather responses from the participants. They were broadly categorized into three sections, each consisting of four questions.

Section 1, Group 1: Types of technologies used and their role in supporting equitable access to education.

Section 2, Group 2: How technology influences teaching methods, student interest, and overall learning outcomes.

Section 3, Group 3: Identifying challenges and limitations of using technology in education and potential solutions.

### 3.3. Data Collection Method

Data was collected from the participants asynchronously to facilitate ease and flexibility of communication. Research items were posted into designated WhatsApp groups created specifically for the discussions. Participants responded to these questions at their convenience. The answers were later gathered in a document for transcription.

### 3.4. Confidentiality and Ethical Considerations

Ethical standards were maintained throughout the entire research process. Respondents were informed about the nature of the research via WhatsApp, and a designated consent form was shared with them prior to data collection. The data was handled and reported anonymously, with access limited solely to the researcher.

## 4. Data Analysis and Results

After gathering responses, a thematic analysis was carried out for analysis and interpretation. The major themes are: 1) accessibility and use of technology in education, 2) impact on student engagement and teaching methods, 3) academic performance enhancement, 4) barriers to technology adoption, and 5) inclusivity and equity in technology integration, with subthemes in many of them.

### 4.1. Main Themes

#### 4.1.1. Accessibility and Use of Technology in Education

The participants detailed the technological tools they use in classrooms to deliver effective lessons. They include Google Classroom, Microsoft Teams, multimedia projectors, assessment tools like Google Forms, and digital libraries,

among others. Several participants across the schools mentioned Zoom and PowerPoint presentations as essential tools in their lessons. Participant 5, Group 1, noted, *“we aim to create an interactive, efficient, and modern learning environment for both students and teachers.”*

They emphasized the support teachers receive by integrating technology into their lessons. Participant 1 highlighted the importance of *animation software* in creating engaging lessons while also simplifying complex concepts. Participant 3 and Participant 5 focused on the ease of streamlining lesson planning and effective communication through the use of interactive presentations and online platforms like Google Classroom.

Participants also linked these technological tools with inclusivity for disadvantaged students. According to Participant 4, *“Now smartphones are almost in everyone’s access, which provides opportunities to get knowledge even to those who are not affluent enough to have education from renowned institutes.”* He further explained that the availability of online lectures has helped make education accessible for students from disadvantaged backgrounds at a low cost. Participant 2 also highlighted the importance of *“MOOCs (Massive Open Online Courses), online degree programs, and educational websites (e.g., Coursera, edX, Khan Academy)”* in offering affordable and flexible learning for students of all backgrounds.

#### 4.1.2. Impact on Student Engagement and Teaching Methods

The responses explain the transformation of teaching styles brought about by technological advancements. Participant 3, Group 2, highlighted that education has become more interactive and accessible through digital collaboration tools like Padlet and Microsoft Teams. She recommended adopting a flipped classroom strategy that allows students to *“learn basic concepts online at home and use classroom time for discussions and problem-solving”*. Participant 5 reinforced this claim by noting that the shift toward blended learning approaches, like using Microsoft Teams and Google Classroom, has given rise to a flexible, student-centered education paradigm.

These interventions are equally effective in enhancing student engagement. Participant 1 stated that this engagement is brought about by interactive methods that have replaced traditional teaching styles. Participant 5 added to the explanation by elaborating that *simulations, videos, and gamified apps make learning more dynamic and appealing*. Participant 4 also supported this claim by including online quizzes and competitions as effective methods to motivate and engage students in the learning process.

Participant 2 highlighted the importance of *“assistive tools like screen readers, text-to-speech software, and speech-to-text applications”* in making content more accessible for students with disabilities or special learning needs. Participant 5 supported this and noted that communication boards and apps assist students with disabilities in expressing themselves and accessing information easily, while Participant 3 focused on screen readers like JAWS and NVDA for visually impaired students, as well as eye-tracking systems, adaptive keyboards, or switch devices that enable such learners to interact easily with computers.

#### 4.1.3. Academic Performance Enhancement

The integration of technology into education has a positive impact on student learning outcomes, according to the participants. Participant 2 noted that personalized learning platforms, like Google Workspace, facilitate students in working at their own pace and focusing on areas that need improvement. Participant 4 cited the example of students *on medical leave for an extended period* who were able to *continue their studies using technology, ensuring they didn’t fall behind*. Participant 5 referenced the COVID-19 pandemic, noting that technology ensured the continuity of education and facilitated collaborative learning. They observed that this is the greatest advantage of technology, enabling students from disadvantaged backgrounds to continue learning even when face-to-face instruction is not feasible.

#### 4.1.4. Barriers to Technology Adoption

Despite the benefits technological integration offers, students remain prone to various barriers that hinder the process. These may include infrastructural challenges, training problems, and connectivity issues, among others. Furthermore, technology is an ever-evolving spectrum, and staying updated with the latest trends may feel overwhelming to many. Participant 1, Group 3, noted, *“Technology is constantly evolving. You get used to one type of tool but then you find out there is a better tool available in the market.”* They also highlighted the need to include these evolutions in the curriculum and policies at the national level.

Another significant barrier is a lack of teacher development programs. Educators who have limited knowledge of technology integration often struggle with these tools and, often, choose not to use them at all. Dependence on internet connectivity is another drawback. Pakistan has many areas that do not have the availability of sufficient infrastructure for technology adoption. This results in the students of such areas being left behind compared to their counterparts in developed areas.

Another critical barrier is the lack of student engagement in online learning environments. Participant 4 observed the difficulty of maintaining student engagement online compared to physical environments. Participant 3 also highlighted *“software glitches and unplanned downtime”* as factors that reduce student engagement and cause frustration among students and teachers alike.

#### 4.1.5. Inclusivity and Equity in Technology Integration

The overall group discussions revolved around the theme of inclusivity in technology interaction and the role it plays in fostering equity in the education sector. Participants highly rated technology in promoting equity and inclusivity by overcoming language and other barriers. Participant 3 cited Google Translate and other AI-driven language applications in

countering language barriers, while Participant 5 noted the multilingual subtitle and translation apps as crucial in bridging cultural gaps among learners.

Participants gave various suggestions to promote equity in education through the integration of technology. Participant 2 suggested using “*basic platforms like WhatsApp for sharing educational resources*” in case the governments do not have enough funds to provide learners in marginalized areas with personal devices or build state-of-the-art computer labs within schools. Participants 1 and 4 emphasized the need for governments to “*equip the institutions with the latest gadgets, as investing in education pays in the long run*” and offer “*subsidized or free internet access*” to all learners to promote inclusion and equity in schools across Pakistan.

## **5. Discussion and Conclusion**

The findings of this study align with the proposed theoretical and conceptual framework, namely, constructivism, sociocultural theory, universal design for learning (UDL), and seamless learning model. The results of this study have been interpreted through the lenses of these frameworks to discuss their implications for using technology to support equitable and inclusive education in line with quality education.

### *5.1. Constructivism and the Role of Technology in Active Knowledge Construction*

These technologies, such as e-learning platforms, multimedia tools, and gamified applications, allow learners to have more interactivity and personalization within their learning experiences. Under a constructivist theory, learners construct knowledge by meaningfully interacting with content and collaborating. Participants also commonly reported that a deeper understanding is fostered by linking academic concepts to real-life problems for students and allowing for self-paced learning with tools like Google Classroom and multimedia presentations.

Additionally, constructivist pedagogy emphasizes the scaffolding process, which is necessary for learners to progress toward independence. This is underscored by respondents' mention of adaptive learning platforms and AI-driven systems that provide individualized support for a range of learners with varying kinds of disabilities or socio-economic disadvantages. Technology here plays the role of “scaffolding,” thus helping learners bridge the gap in understanding and fostering their capability to apply knowledge independently.

### *5.2. Sociocultural Theory: Collaboration and Inclusivity*

Sociocultural theory emphasizes the role of social interaction and cultural tools in learning. The results indicate that digital platforms such as Zoom and Microsoft Teams facilitate opportunities for collaborative learning and global connections, as noted by many participants. These technologies enable real-time feedback, peer-to-peer learning, and participation in diverse, multicultural educational settings.

Also, the aspect of how technology can bridge the cultural and language gaps is present. Participant 3 gave examples of tools such as Google Translate, along with multilingual subtitles, as an essential core to build on for inclusivity. This echoes sociocultural theory, which implies that learning is mediated by tools and symbols through which language allows learners from different walks of life access to, and contribution to, shared knowledge systems.

### *5.3. Universal Design for Learning (UDL): Equity and Accessibility*

The Universal Design for Learning framework promotes designing flexible learning environments suitable for diverse learners. From the results, it can be seen that the UDL principles have been strongly considered, especially in the case of using assistive technologies such as text-to-speech software, screen readers, and adaptive platforms for students with disabilities.

UDL also focuses on multiple representations and means of engagement and expression. In this context, Participant 4 talks about multimedia resources, gamified applications, and personalized learning applications, which all correspond to the diverse range of learners' styles and needs. These findings indicate that technology informed by UDL can go a long way toward mitigating barriers to learning for marginalized and disadvantaged students and advancing equity and inclusion.

### *5.4. Seamless Learning Model: Continuity Across Contexts*

The seamless learning model emphasizes the continuity of learning across formal, informal, physical, and virtual contexts. Participants' descriptions of hybrid and blended learning approaches demonstrate how technology facilitates this continuity: for example, Zoom and Microsoft Teams during the COVID-19 pandemic, where recorded lectures enabled students to learn at their own pace, along with online assignments.

With mobile learning and digital libraries, learners can access resources from anywhere at any time, easily bridging the gap between classroom learning and self-directed exploration. It also aligns with the seamless learning model, which emphasizes allowing learners to transition with as much ease as possible between different learning environments for enhanced student engagement [15].

This research demonstrates the transformative role of emerging technologies in achieving SDG4 by enhancing equitable and inclusive education in Pakistani high schools through technologies such as e-learning platforms and adaptive tools. However, these improve access for marginalized groups and foster active, personalized, and collaborative learning. Yet, infrastructure constraints and inadequate training of teachers remain significant challenges. Addressing these issues through investment, professional development, and inclusive policies, while integrating frameworks like constructivism and UDL, can bridge educational gaps and ensure quality education for all.

## 6. Implications

Educational institutions should utilize technology in active learning ways where students construct knowledge through exploration and application to real life. Adaptation and gamification are tools teachers may use in efforts toward scaffolding to meet individual needs. Curricula should incorporate technologies of collaboration that encourage peer learning and intercultural exchange. Language tools and translation applications should be developed first in order to include in one's immediate environment the widest socio-cultural contexts.

Schools must adopt technologies that offer flexible, accessible, and personalized learning experiences, particularly for students with disabilities or socio-economic challenges. This would ensure equity in educational opportunities. Policy should aim at the development of blended learning environments, equipping students with mobile devices and access to the internet in order to support learning across contexts.

## 7. Limitations and Recommendations

This study poses some limitations that need to be acknowledged. The sample size was insufficient to represent the entire population. Additionally, the collected data was self-reported, which carries the potential for bias, leading to inaccurate results. Although care was taken to involve a diverse group, the participants mostly belonged to rural areas, which limits the possibility of gaining insights into educational institutions in Pakistani rural areas. Furthermore, the research may benefit from a longitudinal study to observe potential differences over longer periods.

The study may also benefit from the inclusion of global perspectives to compare policies and practices across different countries or geographical regions. For a more holistic understanding of the challenges and possible solutions, the sample size must include parents, students, and policymakers as well.

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