Post-pandemic Education: A Survey of Hybrid Learning Models and Educational Equity

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Abstract

In the wake of the COVID-19 pandemic, the educational landscape has undergone significant transformations, necessitating a focus on hybrid learning models, educational equity, technology access, lifelong learning, and the digital divide. This survey paper provides a comprehensive analysis of these evolving paradigms, highlighting the challenges and opportunities they present. The integration of AI and network-enabled technologies has facilitated personalized learning experiences, enhancing educational outcomes while addressing existing disparities. However, the digital divide remains a formidable barrier, particularly for disadvantaged students, underscoring the need for equitable access to digital resources. Hybrid learning models have emerged as a dynamic framework, blending in-person and online instruction to accommodate diverse learner needs, yet their implementation is fraught with challenges, including privacy concerns and the need for robust technological infrastructure. Educational equity, intertwined with social justice, demands systemic reforms to dismantle structural barriers and promote inclusive practices. The role of lifelong learning is increasingly critical in adapting to a rapidly changing job market, with educational institutions playing a pivotal role in supporting continuous education. This paper examines the interconnectedness of these concepts, exploring frameworks and methodologies that underpin effective hybrid learning environments and technological integration. By synthesizing recent research findings, this paper aims to illuminate the path forward for post-pandemic education, proposing strategies to enhance educational equity, bridge the digital divide, and foster lifelong learning. The insights gained from this analysis provide valuable guidance for future research directions and policy development to create resilient and inclusive educational systems.

1 Introduction

1.1 Significance of Post-Pandemic Education

The post-pandemic landscape necessitates a transformative approach to education, emphasizing resilience, adaptability, and inclusivity. The COVID-19 pandemic intensified existing educational inequalities, disproportionately impacting disadvantaged students and underscoring the urgent need to address these disparities [1]. The integration of AI and network-enabled technologies has become crucial, providing personalized learning experiences that cater to diverse student needs and enabling institutions to develop adaptive technology platforms that enhance learning and operational strategies [2].

Transformative social and emotional learning (SEL) plays a vital role in promoting educational equity and excellence, particularly in addressing racial and ethnic disparities [3]. The incorporation of collective intelligence in online learning environments has demonstrated potential in improving academic performance among disadvantaged students, highlighting the significance of innovative educational strategies in this era [4].

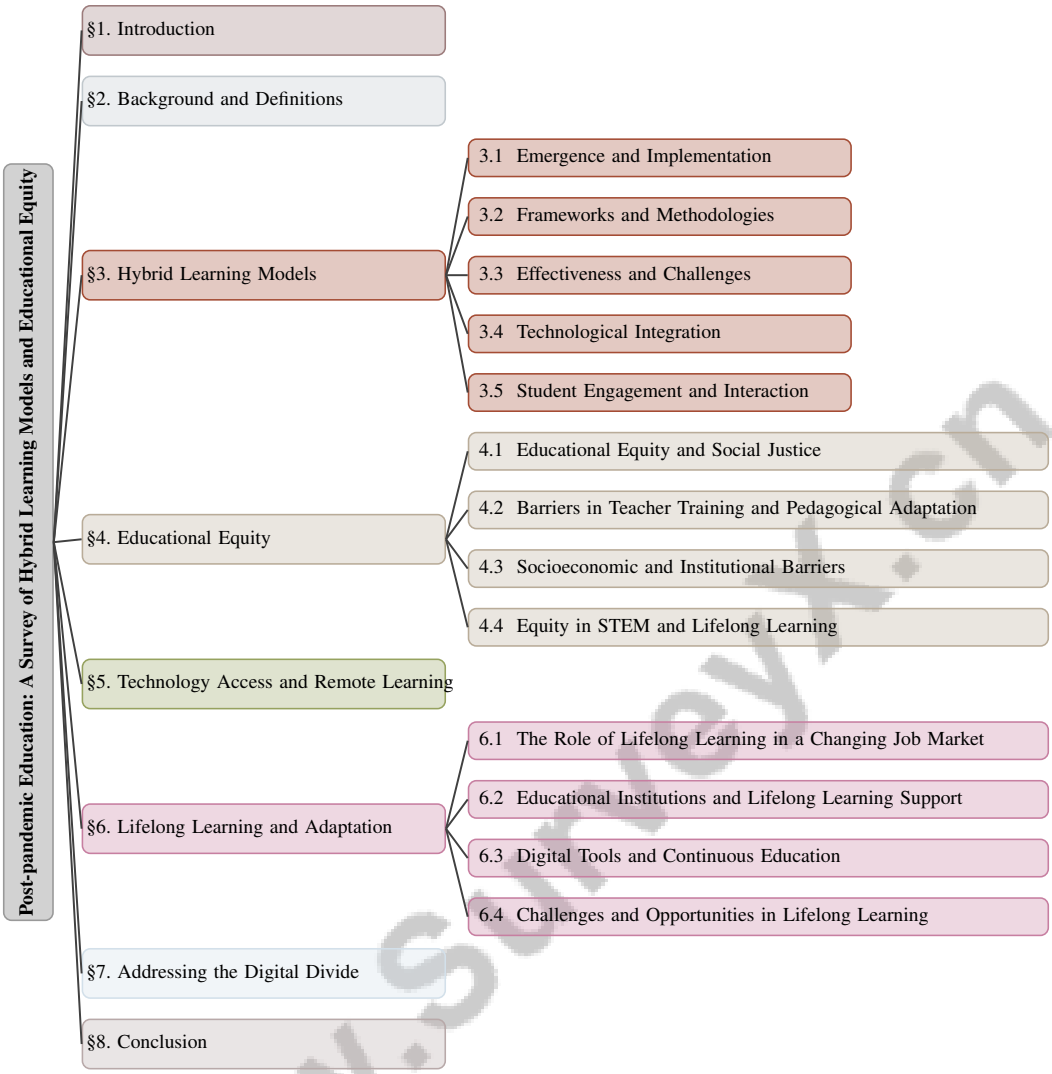


Figure 1: chapter structure

The pandemic has also driven the development of effective hybrid learning models, especially in specialized programs like Doctor of Physical Therapy (DPT), where a combination of online and in-person instruction is essential for comprehensive education [5]. Furthermore, alternative educational tools, such as online gaming, have emerged as engaging and effective remote learning methods [6].

Challenges in implementing equitable educational practices, such as those experienced in the San Francisco Unified School District, reveal the complexities of aligning educational models with community values and transparency [7]. As educational institutions adapt to the post-pandemic reality, there is an imperative to create inclusive and equitable learning environments that address the diverse needs of all students, leveraging technology and innovative pedagogical approaches to bridge the digital divide.

1.2 Global Impact of COVID-19 on Education

The COVID-19 pandemic instigated a profound shift in educational paradigms worldwide, necessitating a swift transition to remote learning modalities. This shift exposed the limitations of traditional educational models, particularly their effectiveness in facilitating remote instruction [8]. The pandemic highlighted critical disparities in digital infrastructure access, exacerbating the digital divide and raising concerns regarding equitable participation and educational outcomes [9].

In computer science education, both instructors and students encountered unique challenges in adapting to remote learning, emphasizing the need for innovative pedagogical strategies to support effective learning experiences [10]. The pandemic's repercussions extended beyond academics, impacting societal well-being and psychological states, which in turn affected educational engagement and performance [11]. Innovative teaching approaches, such as virtual reality, emerged as potential solutions to mitigate the disruptions caused by the pandemic [12].

The transition to hybrid learning models, particularly in fields requiring practical experience like physical therapy, exemplified the adaptations necessary to maintain educational efficacy [5]. Moreover, the pandemic underscored the importance of effective student engagement strategies for disadvantaged students to improve academic outcomes in online learning environments [4]. Analyzing Wi-Fi usage across campus buildings provided insights into student behavior during remote learning, highlighting the need to address students' digital needs [2].

Lecturers faced significant challenges in providing feedback during remote learning, particularly in large classes, which emphasized the necessity for quality education and effective communication strategies [13]. The global educational landscape has been irrevocably altered, prompting a reevaluation of pedagogical practices and the development of resilient educational frameworks capable of withstanding future crises.

1.3 Transition from Emergency Remote Teaching

The COVID-19 pandemic necessitated an immediate shift to emergency remote teaching (ERT), revealing significant challenges within global educational systems. Unlike structured online learning environments, ERT was implemented rapidly, often lacking the necessary infrastructure and pedagogical strategies for effective teaching and learning [14]. This abrupt transition impacted not only educational quality but also the mental health of students and educators, who struggled with the sudden change in learning modalities [14].

Web behavior data from Google Trends during the pandemic reflected the widespread interest and pressing needs of both students and educators in adapting to online learning environments, highlighting the significant challenges faced [8]. The transition exacerbated existing educational inequalities, as students from disadvantaged backgrounds faced limited access to digital resources and stable internet connections, further hindering their learning experiences [1].

In response, educational institutions began exploring sustainable hybrid learning models that integrate both in-person and online instruction, leveraging the strengths of each modality to create a more resilient educational framework. Cooperative dynamics within online discussion forums have been shown to enhance learning outcomes for disadvantaged students, demonstrating the potential of hybrid models to address educational disparities [4].

The transition from Emergency Remote Teaching (ERT) to hybrid learning necessitates a thorough examination of the challenges encountered during the pandemic, including inadequate access to technology and emotional support, alongside the implementation of innovative pedagogical strategies that utilize both physical and digital learning environments. [15, 16, 17, 18, 19]. By integrating face-to-face and online modalities, hybrid learning models present a promising solution to the limitations observed during ERT, paving the way for more effective and equitable educational practices in the post-pandemic era.

1.4 Purpose and Structure of the Survey Paper

This survey paper aims to conduct a comprehensive analysis of the evolving educational landscape in the post-pandemic era, focusing on the integration of hybrid learning models and the pursuit of educational equity, while addressing challenges posed by emergency remote teaching and the need for pedagogical innovation in response to significant disruptions experienced by students and educators globally [20, 19]. By synthesizing recent research findings, this paper seeks to illuminate the challenges and opportunities presented by the shift in educational paradigms necessitated by the COVID-19 pandemic and explore how educational institutions can effectively integrate technology and innovative pedagogical strategies to foster inclusive and equitable learning environments.

The paper is structured into several key sections, each addressing critical aspects of post-pandemic education. The introduction discusses the significance of education in this new landscape and the

global impact of COVID-19 on education systems. The background section provides definitions and explores the interconnectedness of concepts such as hybrid learning, educational equity, and technology access.

Subsequent sections delve into hybrid learning models, examining their emergence, implementation, effectiveness, and challenges, as well as the role of technological integration in enhancing learning experiences and fostering student engagement.

The survey further investigates educational equity, emphasizing principles of social justice, barriers in teacher training, and the impact of socioeconomic and institutional factors. It also addresses the importance of promoting equity in STEM education and enhancing lifelong learning opportunities, highlighting the need for context-specific strategies to tackle barriers faced by underrepresented groups in these fields [21, 22, 23, 24, 25]. The discussion on technology access and remote learning underscores the importance of overcoming digital divides to support effective remote learning experiences.

The paper concludes with a comprehensive analysis of lifelong learning and adaptation, emphasizing the pivotal roles of educational institutions and digital tools in facilitating continuous education. It underscores the necessity for universities to evolve beyond traditional educational models to accommodate a diverse range of learners at various life stages, particularly in the context of digitalization. Findings reveal that effective lifelong learning programs must integrate both formal and informal learning processes, ensuring that students can enhance their skills and competencies through flexible, digitally-supported environments [26, 27]. Finally, the survey addresses the digital divide, reviewing initiatives and policies aimed at ensuring equitable access to digital resources for all learners. Through this structured approach, the paper aims to provide valuable insights and propose future research directions to enhance post-pandemic education.The following sections are organized as shown in Figure 1.

2 Background and Definitions

2.1 Interconnectedness of Key Concepts

The post-pandemic educational landscape is shaped by the interrelation of hybrid learning models, educational equity, technology access, lifelong learning, and the digital divide. Hybrid learning, which combines in-person and online instruction, is crucial for addressing diverse student needs. However, digital inequalities, especially prevalent in advanced economies, challenge the equitable implementation of these models [28]. These inequalities are evident in disparities in access to and effective use of digital resources, which are essential for the success of hybrid learning environments.

Educational equity strives to provide equal success opportunities for all students, irrespective of socioeconomic status. The digital divide, exacerbated by these socioeconomic disparities, significantly hinders this goal [29]. Vulnerable groups, particularly those with limited access to digital technologies, face considerable barriers in accessing educational resources, which impedes their learning opportunities [1]. Additionally, demographic biases in spatio-temporal data can further complicate the equitable distribution of educational resources and opportunities [30].

Lifelong learning is increasingly significant in response to changing job markets and societal demands. Conventional e-learning environments often apply a 'one size fits all' approach, overlooking the diverse learning styles and hindering lifelong learning initiatives [31]. Adaptive learning technologies are vital for fostering self-regulated learning processes and offering personalized education tailored to individual needs.

The digital divide impacts not only access to educational services but also the broader socio-technical landscape, including disparities in access to and knowledge of emerging technologies like generative AI [29]. Recognizing these interconnected concepts is crucial for developing strategies that promote inclusive and resilient educational practices in the post-pandemic era. A comprehensive approach addressing the socio-technical challenges posed by rapid digital evolution is essential for bridging these divides and ensuring equitable education access for all.

Category	Feature	Method
Frameworks and Methodologies	User Interaction Design	DTB[32]
Effectiveness and Challenges	Blended Learning Approach	CUAAF[33], HL[18], CoSA[11], HL[34], ALE[31]
Technological Integration	Personalized Learning	PAL-I[35], HLE[36]
Student Engagement and Interaction	Immediate Response Mechanism	ATT[37]

Table 1: This table provides a comprehensive summary of various frameworks and methodologies employed in hybrid learning environments. It categorizes the methods based on their focus areas, such as user interaction design, blended learning approaches, personalized learning, and immediate response mechanisms, highlighting their relevance and application in enhancing educational practices. The table references specific studies that contribute to the understanding and implementation of these methods within the context of hybrid learning models.

3 Hybrid Learning Models

As educational institutions increasingly adopt hybrid learning models, it becomes essential to understand the foundational elements that underpin their effectiveness. Table 1 presents a detailed overview of the frameworks and methodologies integral to the development and effectiveness of hybrid learning models, bridging traditional educational practices with advanced technological integration. Additionally, Table 5 offers a detailed comparison of these frameworks and methodologies, illustrating the integration of traditional educational practices with advanced technologies. This section delves into the emergence and implementation of these models, exploring how they have evolved in response to contemporary educational challenges, particularly those exacerbated by the COVID-19 pandemic. By examining the key factors that contribute to the successful integration of hybrid learning, we can better appreciate the transformative potential of this approach in reshaping educational practices.

3.1 Emergence and Implementation

Method Name	Technological Integration	Implementation Challenges	Engagement Strategies
PAL-I[35]	Advanced Algorithms	Privacy Concerns	Tailored Feedback
HL[18]	Integrasikan Teknologi Langsung	Infrastruktur Teknologi	Interaksi Aktif

Table 2: Comparison of Hybrid Learning Models: This table presents a comparative analysis of two hybrid learning methods, focusing on their technological integration, implementation challenges, and engagement strategies. The insights provided highlight the diverse approaches and potential obstacles in effectively deploying hybrid educational frameworks.

The emergence and implementation of hybrid learning models have been pivotal in reshaping educational practices, particularly in response to the exigencies brought about by the COVID-19 pandemic. These models, which seamlessly integrate in-person and online instruction, provide a dynamic and flexible learning framework that accommodates diverse learner needs and preferences [35]. The hybrid approach stands out for its ability to offer a more interactive and personalized learning experience compared to traditional or purely online methods [18].

A notable aspect of hybrid learning is the incorporation of advanced technologies such as virtual reality (VR) and augmented reality (AR), which enhance user engagement through immersive educational experiences. For instance, the design of immersive VR classrooms, which considers elements like student seating arrangements and avatar styles, has been shown to optimize peer interaction and learning outcomes [38]. The shift towards immersive learning is further exemplified by initiatives such as VR tours, which transform traditional methods into more engaging and interactive experiences [12].

The integration of hybrid learning models in specialized programs, such as Doctor of Physical Therapy (DPT) education, highlights the need for program-level implementation strategies that effectively blend online and in-person instruction to ensure comprehensive educational experiences [5]. Additionally, the use of online gaming during the pandemic has been explored as a means of enhancing student learning, underscoring the potential of integrating diverse digital tools into educational practices [6].

However, the implementation of hybrid learning models is not without challenges. A significant hurdle is the development of effective personalized strategies that cater to the diverse needs and preferences of learners [35]. Privacy concerns and security implications associated with online proctoring methods present additional challenges, as educators and students navigate the complexities of maintaining assessment integrity in remote settings [39]. Furthermore, the rapid transition to hybrid learning has highlighted the need for robust technological infrastructure and support systems, as evidenced by the analysis of cloud computing models used by Chinese universities during the pandemic [40].

The role of discussion forums in enhancing engagement and academic performance, especially for students with lower prior performance, is an important consideration in the design of hybrid learning environments [4]. Additionally, the use of platforms like Sakai for anonymous peer review has been studied, demonstrating its potential to foster student engagement and improve learning outcomes in hybrid settings [13].

Table 2 provides a detailed comparison of hybrid learning methods, elucidating the technological integrations, implementation challenges, and engagement strategies associated with each approach. Figure 2 illustrates the key components and challenges of hybrid learning models, highlighting technological enhancements, implementation challenges, and engagement strategies. This visual representation serves to synthesize the aforementioned discussions and provides a clearer understanding of how these elements interplay within the hybrid learning framework.

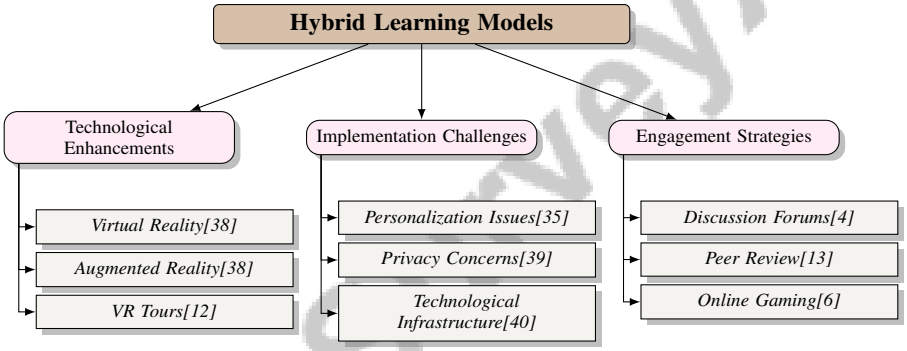


Figure 2: This figure illustrates the key components and challenges of hybrid learning models, highlighting technological enhancements, implementation challenges, and engagement strategies.

3.2 Frameworks and Methodologies

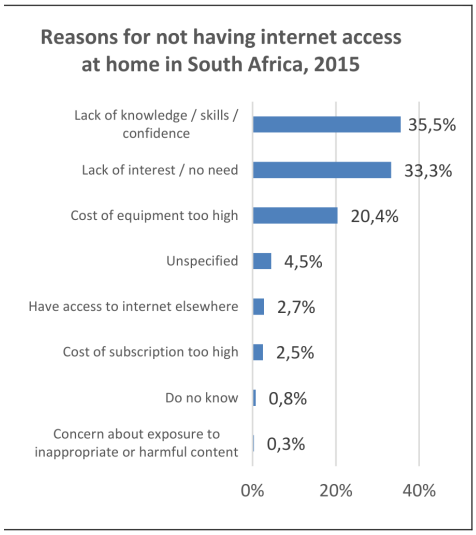
The development of hybrid learning environments relies on a variety of frameworks and methodologies designed to integrate digital technology with traditional educational practices effectively. A significant aspect of these methodologies is the emphasis on a pedagogy-first approach, which prioritizes educational objectives and teaching strategies over the mere adoption of technology [41]. This approach ensures that digital tools are used to enhance, rather than replace, traditional pedagogical methods, facilitating a more coherent and effective learning experience.

One of the innovative methodologies in hybrid learning involves the use of adaptive learning systems, which are designed to dynamically adjust to the individual needs of learners. These systems utilize cloud computing to provide personalized learning experiences that cater to different learning styles and paces, thereby improving student engagement and understanding [42]. The integration of personalized adaptive learning interfaces further enhances this approach by increasing learner satisfaction and motivation [35].

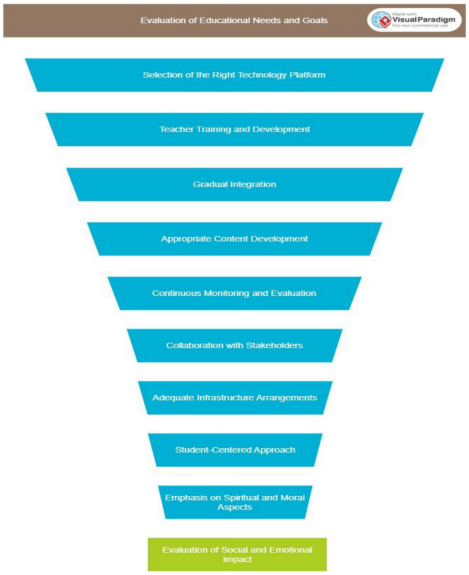
In the realm of science education, hybrid learning methodologies often combine online and offline strategies to improve student participation and comprehension of complex concepts. This blend of learning modalities enables students to engage with content in diverse ways, fostering a deeper understanding of the material [43]. Additionally, the use of asynchronous content delivery, coupled with interactive synchronous sessions, has been shown to enhance student engagement and provide flexibility in learning [10].

The Digital Twin Builder exemplifies another innovative framework in hybrid learning environments. This platform allows educators to create virtual learning applications through a user-friendly drag-and-drop interface, utilizing generic models for efficiency. Such tools enable the creation of immersive and interactive learning experiences that can simulate real-world scenarios, thereby enriching the educational process [32].

Overall, the successful implementation of hybrid learning models depends on the careful selection and integration of frameworks and methodologies that align with educational goals and learner needs. By utilizing adaptive learning systems that tailor educational content and strategies to individual learners, along with personalized interfaces and cutting-edge digital tools, educators can foster dynamic and inclusive learning environments. These environments are designed to accommodate diverse learning styles and enhance student engagement, satisfaction, and outcomes, ultimately promoting academic success in the evolving landscape of post-pandemic education. The integration of these technologies not only addresses the varied needs of learners but also supports the transition towards a more flexible and effective educational framework that bridges online and in-person learning experiences. [44, 19, 35]



(a) Reasons for not having internet access at home in South Africa, 2015[45]



(b) Evaluation of Educational Needs and Goals[46]

Figure 3: Examples of Frameworks and Methodologies

As shown in Figure 3, In the exploration of hybrid learning models, it is crucial to consider the frameworks and methodologies that underpin successful implementation. The provided examples illustrate key aspects of these frameworks. The first visual, a bar chart, highlights the barriers to internet access in South Africa as of 2015, such as lack of knowledge, interest, and the high cost of equipment. These barriers are essential considerations for developing hybrid learning environments, as they influence the accessibility and inclusivity of educational technologies. The second visual, a flowchart, outlines a comprehensive framework for evaluating educational needs and goals, emphasizing the importance of selecting the right technology platform, training educators, and ensuring continuous monitoring and evaluation. Together, these examples underscore the multifaceted approach required to effectively integrate technology into education, addressing both infrastructural challenges and pedagogical strategies to foster an inclusive and effective learning environment. [**?**]chetty2018bridging,alfiyanto2024integration)

3.3 Effectiveness and Challenges

Hybrid learning models have emerged as a pivotal educational innovation, blending traditional and digital methodologies to cater to diverse learning preferences and needs. Their effectiveness is

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Benchmark	Size	Domain	Task Format	Metric
DAC[47]	320,000	Digital Accessibility	Geodemographic Classification	Upload Speed, Download Speed
COVID-OLB[8]	21	Online Learning	Web Behavior Analysis	Search Interest

Table 3: This table presents a comparison of two representative benchmarks in the context of digital accessibility and online learning. It details the size, domain, task format, and metrics used for each benchmark, providing a comprehensive overview of their characteristics and evaluative criteria.

particularly evident in the flexibility they offer, allowing students to access educational content both in-person and online. This adaptability enhances accessibility and convenience, making hybrid learning a preferred method in the post-pandemic era, with a significant proportion of students favoring it over purely online or offline methods [18]. Furthermore, hybrid learning strategies, when combined with students' self-efficacy, have been shown to positively impact learning outcomes, particularly in understanding and applying scientific concepts [34].

Table 3 provides a comparative analysis of representative benchmarks pertinent to the challenges and effectiveness of hybrid learning models, highlighting their domains, task formats, and evaluation metrics.

However, the implementation of hybrid learning models is fraught with challenges. A primary concern is ensuring exam integrity and validating student identities during remote assessments, which undermines the effectiveness of current evaluation methods [33]. The integration of advanced technologies like virtual reality (VR) and augmented reality (AR) into hybrid environments is also hindered by resistance from traditional educational practices, high implementation costs, and a lack of clear instructional designs for effective integration [48].

Privacy concerns pose additional challenges, particularly regarding students' discomfort with invasive monitoring techniques and the lack of alternatives to mandatory online proctoring [39]. The transition from traditional to hybrid teaching formats requires significant adaptation of teaching methods, equitable access to learning resources, and maintenance of student engagement and assessment integrity in virtual environments [10]. Moreover, the psychological impacts of the pandemic, including increased negative sentiments and anxiety, further complicate the learning experience, with studies indicating a substantial increase in negative sentiments during the pandemic [11].

The challenges in hybrid learning environments extend to technical difficulties, such as those encountered with platforms like Edmodo, which include issues with student participation and the necessity for reliable internet access [36]. Furthermore, inadequate preparation for pre-class materials, limited student interaction, and the absence of visual feedback in online settings complicate teachers' ability to effectively gauge and enhance student engagement. The difficulty learners face in extracting information when seated in the back of virtual classrooms further hinders their learning experience [38].

Despite these challenges, hybrid learning models offer significant potential for enhancing educational outcomes. The use of adaptive e-learning environments has been shown to significantly improve student engagement compared to conventional methods, highlighting the importance of tailoring educational experiences to individual learning styles [31]. Additionally, the effectiveness of hybrid learning models can be analyzed through the lens of discussion forum participation, which has shown positive correlations with improved academic performance among disadvantaged students [4].

3.4 Technological Integration

Method Name	Technological Tools	Learning Flexibility	Integration Frameworks
PAL-I[35]	-	Personalized Adaptive Learning	Adaptive Learning Technologies
HLE[36]	Edmodo Platform	Flexible Learning Experience	Hybrid Approach

Table 4: This table presents a comparative analysis of two hybrid learning methods, PAL-I and HLE, highlighting their technological tools, learning flexibility, and integration frameworks. The table underscores the diversity in technological integration approaches and their impact on personalized and flexible learning experiences.

The integration of technology into hybrid learning models is pivotal in enhancing educational experiences by providing a dynamic, interactive, and personalized learning environment. The adaptability of educators to new teaching methodologies has been a significant factor in the successful incorporation of technology in education, as highlighted by the survey on hybrid learning [49]. This adaptability is crucial for creating learning environments that are responsive to the diverse needs of students, offering personalized experiences that adjust to individual learning paces and preferences, thereby improving engagement and learning outcomes [35].

A key aspect of technological integration in hybrid learning is the use of Virtual Reality (VR) and Augmented Reality (AR) applications, which have been shown to significantly enhance student engagement and learning outcomes compared to traditional methods [48]. These immersive technologies provide students with interactive and realistic learning experiences, such as VR photo-based tours that allow students to virtually explore environments and learn in contextually rich settings [12].

Cloud computing plays a vital role in supporting hybrid learning models by providing scalable and flexible infrastructure for educational activities. The categorization of cloud services into models such as Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS), along with deployment models like public, private, community, and hybrid, offers a framework for understanding the diverse applications of cloud computing in education [40]. These services enable the synchronization of learning management systems (LMS) and social networking tools, facilitating seamless interaction and collaboration among students and educators.

The hybrid approach benefits from combining face-to-face interactions with online resources, allowing students to engage in learning activities beyond the constraints of time and space [36]. This approach is supported by frameworks that integrate both online and in-person learning strategies, ensuring that educational practices are grounded in sound educational theory [5]. Table 4 provides a detailed comparison of hybrid learning methods, illustrating the technological tools, learning flexibility, and integration frameworks that characterize each approach.

Asynchronous materials and interactive synchronous sessions are also integral to hybrid learning environments, providing students with flexibility and opportunities for mastery-based learning [10]. These elements, along with the categorization of VR classroom designs based on factors such as student positioning and peer interaction dynamics, contribute to the development of effective hybrid learning environments [38].

3.5 Student Engagement and Interaction

The effectiveness of hybrid learning models significantly hinges on fostering robust student engagement and interaction. One innovative strategy to enhance engagement is the use of real-time feedback tools that monitor students' attention levels during online classes. For instance, gaze-tracking technology has been proposed to alert teachers when a student's attention drops below a predetermined threshold, allowing for timely interventions to re-engage students [37]. This approach not only helps maintain a high level of engagement but also provides valuable insights into student behaviors and learning patterns.

Interactive technologies, particularly Virtual Reality (VR) and Augmented Reality (AR), are increasingly vital in enhancing student engagement within hybrid learning environments. These technologies facilitate immersive educational experiences that transcend traditional classroom limitations, enabling access to virtual laboratories, industrial simulations, and medical scenarios that would otherwise be inaccessible. As advancements in consumer technology and increased investments from major companies improve the accessibility of VR and AR, educational institutions can leverage these tools to support diverse learning styles and create more dynamic, interactive learning spaces. This shift not only fosters greater interaction among students—both on-site and remote—but also addresses some of the pedagogical and technological challenges associated with synchronous hybrid learning environments [48, 38, 50]. These technologies create immersive experiences that encourage active participation and collaboration among students. By simulating real-world scenarios, VR and AR facilitate experiential learning, making abstract concepts more tangible and easier to understand.

Discussion forums and collaborative online platforms further enhance engagement by providing students with opportunities to interact with peers and instructors outside the traditional classroom setting. These platforms support asynchronous and synchronous interactions, allowing students to engage in meaningful discussions and collaborative projects at their own pace [4]. The use of such

platforms has been shown to improve academic performance, particularly for disadvantaged students, by fostering a sense of community and belonging within the learning environment.

Moreover, the integration of social networking tools with learning management systems (LMS) facilitates seamless communication and collaboration, enabling students to connect and share resources effectively. This integration supports a blended learning approach that combines the strengths of face-to-face and online interactions, promoting a more holistic educational experience [40].

In examining the complexities of educational equity, it is essential to acknowledge the multifaceted challenges and adaptations that arise within this domain. The hierarchical structure of these challenges is not only intricate but also underscores the interconnectedness of various factors contributing to educational disparities. Figure 5 illustrates this concept effectively, depicting how social justice, technological disparities, teacher training, socioeconomic barriers, and STEM education collectively influence the creation of inclusive learning environments. This figure also highlights key strategies for enhancing student engagement in hybrid learning environments, emphasizing the use of real-time feedback tools, interactive technologies, and collaborative platforms to foster interaction and participation. By visualizing these relationships, we can better understand the systemic nature of educational equity and the need for comprehensive strategies to address these challenges.

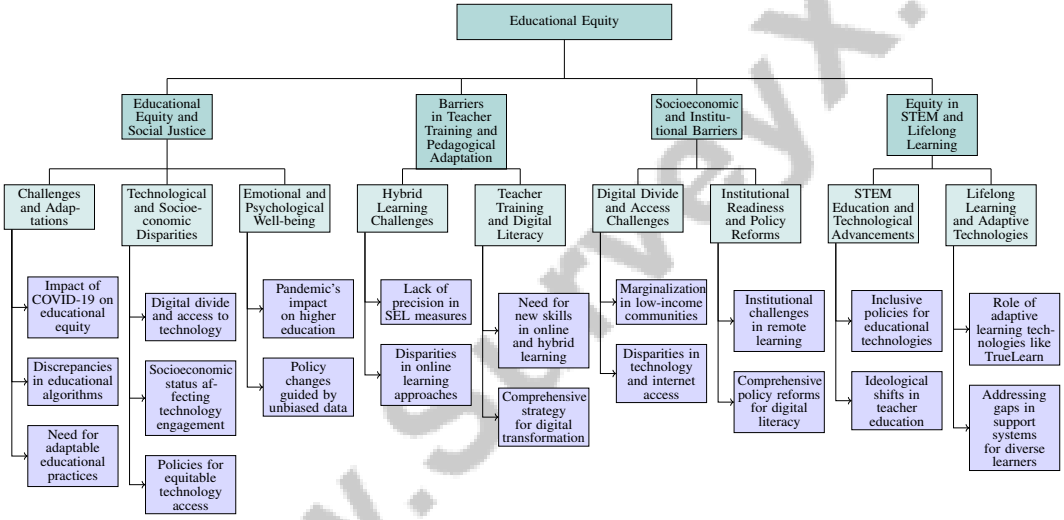

Figure 4: This figure illustrates the hierarchical structure of educational equity challenges and adaptations, emphasizing the interconnectedness of social justice, technological disparities, teacher training, socioeconomic barriers, and STEM education in fostering inclusive learning environments.

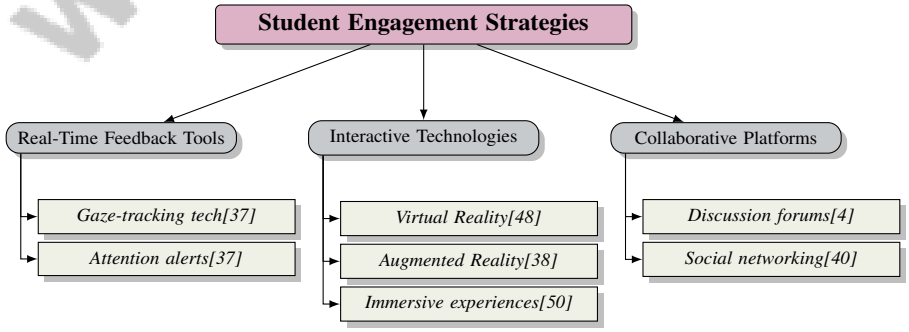

Figure 5: This figure illustrates key strategies for enhancing student engagement in hybrid learning environments, highlighting the use of real-time feedback tools, interactive technologies, and collaborative platforms to foster interaction and participation.

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Feature	Emergence and Implementation	Frameworks and Methodologies	Effectiveness and Challenges
Technological Integration	Ar, VR Technologies	Adaptive Learning Systems	Vr, AR Applications
Implementation Challenges	Privacy, Infrastructure Issues	Pedagogy-first Approach	Exam Integrity, Privacy
Student Engagement	Interactive Experiences	Personalized Interfaces	Flexible Learning Formats

Table 5: This table provides a comprehensive comparison of key features associated with hybrid learning models, focusing on technological integration, implementation challenges, and student engagement. It highlights the emergence and implementation of these models, the frameworks and methodologies employed, and the effectiveness and challenges encountered in their application. The table serves as a valuable resource for understanding the multifaceted nature of hybrid learning and its potential to transform educational practices.

4 Educational Equity

4.1 Educational Equity and Social Justice

Educational equity, intertwined with social justice, is essential in addressing disparities highlighted by the COVID-19 pandemic. It ensures fair access to educational resources for all students, aligning with social justice goals to dismantle structural barriers [1]. The pandemic has amplified challenges in achieving educational equity, as seen in the discrepancies between educational algorithms' intended outcomes and their actual effectiveness in fostering equity and community engagement [7].

The shift to remote learning underscores the need for adaptable educational practices that accommodate diverse student needs. Personalized learning approaches are crucial for improving educational outcomes and reducing educators' administrative burdens [51]. Integrating social and emotional learning (SEL) is vital for fostering engaged citizenship and promoting social justice [3]. Immersive technologies, such as Virtual Reality (VR), enhance learner engagement and motivation by offering interactive educational experiences [38].

Addressing socioeconomic disparities is imperative as research shows students from higher socioeconomic status (SES) neighborhoods engage more actively with educational technologies, while lower SES students often use technology for recreation. This digital divide necessitates policies ensuring equitable access to technology and resources, maximizing digital advancements' educational benefits [1]. Enhancing digital literacy through self-directed learning and educator support is essential for improving students' digital skills.

The pandemic's impact on emotional and psychological well-being, particularly in higher education, complicates the pursuit of educational equity and social justice [5]. Addressing these inequities requires understanding local factors influencing educational practices and policies. Effective policy changes must translate research opportunities into practice, guided by comprehensive and unbiased data [30].

4.2 Barriers in Teacher Training and Pedagogical Adaptation

The transition to hybrid learning models has exposed barriers in teacher training and pedagogical adaptation, crucial for achieving educational equity post-pandemic. A significant challenge is the lack of precision in constructs and measures of social and emotional learning (SEL), along with inadequate training for educators to implement effective SEL practices [3]. This gap affects educators' ability to integrate SEL into hybrid environments, impacting educational equity.

The pandemic's shift to online learning revealed disparities in how countries approached this transition, with existing benchmarks failing to capture national effectiveness in online learning [8]. This limited understanding complicates efforts to adapt pedagogical practices to hybrid models.

Barriers in teacher training and pedagogical adaptation hinder effective engagement in online learning environments, especially for disadvantaged students [4]. These include the need for educators to develop new skills for facilitating online and hybrid learning effectively. The absence of targeted training programs equipping educators with essential digital literacy and adaptive teaching methods exacerbates these challenges, leading to inequities in student engagement and learning outcomes.

A comprehensive strategy is necessary to address these barriers to educational equity and digital transformation. This strategy should re-evaluate teacher training programs to incorporate digital

literacy and adaptive pedagogical methods, foster inclusive practices tailored to diverse learner needs, and ensure equitable access to technological resources. Additionally, developing and managing digital training programs must be standardized and responsive to the digital economy's evolving demands, as emphasized by research highlighting contextual analysis's importance in promoting inclusion and equity in education systems [45, 52, 25]. Overcoming these challenges enables educational institutions to support diverse learning needs and advance educational equity in the post-pandemic landscape.

4.3 Socioeconomic and Institutional Barriers

Socioeconomic and institutional barriers significantly impact educational equity, particularly post-pandemic. Low-income communities often face marginalization, lacking access to essential information technology resources and skills, leading to economic and social disenfranchisement [53]. The digital divide, a complex challenge, encompasses disparities in access, capability, and outcomes, reflecting difficulties in integrating digital tools into education [54].

Access to technology and the internet is disproportionately higher among wealthier students, while socioeconomically disadvantaged groups encounter severe limitations [9]. Insufficient internet access and financial constraints impede students' ability to engage in remote learning and access educational resources [16]. The lack of technological devices and the need for emotional support during crises further hinder disadvantaged students' educational experiences.

Institutional challenges also perpetuate these inequities. Varying infrastructure capabilities of educational institutions and the rapid need for adaptation to remote learning models highlight disparities in readiness and capacity [40]. Many studies overlook these disparities, significantly impeding remote learning efforts' effectiveness [55]. Additionally, reliance on anonymized data in research may fail to accurately capture individual behaviors or preferences, leading to potential inaccuracies in understanding digital access issues [2].

Socioeconomic status determines digital skills, with age, income, and education playing pivotal roles in shaping these abilities [56]. Education emerges as the strongest predictor of interest in emerging technologies like ChatGPT, with higher engagement in urbanized, educated, and economically advantaged regions [29]. This highlights the need for comprehensive policy reforms and targeted interventions to bridge the digital divide and promote digital literacy among disadvantaged populations.

The historical context of institutions such as the University of the Western Cape illustrates demographic challenges relevant to socioeconomic barriers affecting educational equity [13]. Addressing these barriers necessitates a holistic approach encompassing policy reforms, enhanced digital access, and inclusive pedagogical strategies. By tackling these challenges, educational institutions can strive for greater equity and ensure that all students have the opportunity to succeed in the post-pandemic educational landscape.

4.4 Equity in STEM and Lifelong Learning

Equity in STEM education and lifelong learning is critical in the post-pandemic educational landscape, where technological advancements and evolving job markets necessitate continuous skill adaptation. Educational technologies, such as generative AI, offer significant potential for enhancing learning experiences but risk exacerbating existing disparities if not implemented with inclusive policies addressing the digital divide [57]. Ensuring these technologies serve as tools for educational equity rather than reinforcing structural inequalities is essential.

Achieving equity in STEM education requires educators to undergo ideological shifts prioritizing dismantling structural barriers. Teacher education programs must equip educators with the tools necessary to confront these inequalities, promoting educational equity [58]. Such shifts are crucial for fostering inclusive learning environments that support diverse student needs and promote equal opportunities in STEM fields.

Lifelong learning, facilitated by adaptive learning technologies like TrueLearn, plays a vital role in personal and professional development. TrueLearn's scalability and transparency, alongside its ability to integrate multiple engagement drivers, enhance personalized learning experiences, making it a valuable tool for supporting lifelong learning [59]. These technologies offer learners

tailored educational pathways aligned with their individual growth and skill mastery, as indicated by frameworks providing insights into the dynamics of learning across various timescales [60].

The transition to online learning during the pandemic exposed significant gaps in support systems, particularly regarding equitable access to educational opportunities [61]. Addressing these gaps necessitates a comprehensive understanding of the unique challenges faced by diverse learner populations, including those with special needs. Optimizing emerging platforms such as the metaverse for educational purposes remains an ongoing research area, focusing on ensuring accessibility and inclusivity for all students [62].

Furthermore, disparities in technology access and financial stability have highlighted the uneven capacity of students to engage effectively with emergency remote teaching (ERT) [16]. Future research should prioritize addressing digital equity and safeguarding student privacy and security to create more equitable learning environments [6].

5 Technology Access and Remote Learning

5.1 Importance of Technology Access in Remote Learning

Technology access is crucial for remote learning, forming the backbone of educational engagement and success in the post-pandemic era. The integration of technology, such as virtual labs and AI-driven platforms, enhances student engagement and self-efficacy by providing personalized learning experiences tailored to diverse needs [51]. The COVID-19 pandemic underscored the necessity of a robust technological infrastructure to support online education, revealing significant disparities in technology access, especially among disadvantaged students who depend on digital platforms for academic improvement [9, 4].

Immersive technologies like virtual reality enhance remote learning by creating engaging environments that improve learning outcomes [12]. Reliable internet access is fundamental, as highlighted by analyses of Wi-Fi device connectivity in educational facilities [2]. Despite technology's transformative potential, challenges such as financial constraints, skill gaps, and accessibility issues persist, impeding effective digital tool engagement [8]. Addressing these challenges is essential to bridge the digital divide and ensure equitable educational resource access.

5.2 Strategies to Improve Technology Access

Improving technology access for remote learning is vital for closing the digital divide and promoting equitable education. Establishing e-learning centers in rural areas, supported by centralized Learning Management Systems (LMS), can significantly enhance access to educational resources [63]. These centers serve as hubs for digital literacy programs, equipping individuals with essential skills to effectively navigate digital technologies [64].

Community-based initiatives play a crucial role in promoting digital literacy and technology access by addressing local needs and utilizing community resources to provide tailored support and training [64]. Such programs are key to overcoming social and cultural barriers that often hinder technology adoption [65]. Continuous investment in digital infrastructure and skills development is necessary due to the recursive nature of technological adoption [66]. Ensuring affordable broadband access, particularly in marginalized communities, is critical, as regulatory challenges related to spectrum allocation can further restrict access [67]. Overcoming these barriers is essential for expanding technology access and fostering digital inclusion.

Enhancing information literacy is also crucial for achieving equitable learning outcomes in technology-mediated environments [54]. By incorporating information literacy into curricula and providing targeted training, institutions can empower learners to critically engage with digital content.

5.3 Impact of Emerging Technologies

Emerging technologies have significantly transformed remote learning and technology access, offering both opportunities and challenges in achieving educational equity. Innovative tools like artificial intelligence, virtual reality, and augmented reality enrich the learning experience by creating person-

alized and immersive educational environments, promoting interactive learning that caters to diverse student needs and enhances collective intelligence [4].

Culturally responsive pedagogy is vital in leveraging emerging technologies to foster transformative social and emotional learning (SEL). By integrating students' cultural backgrounds into the educational process, educators can create inclusive and engaging experiences that enhance student engagement and foster a sense of belonging and motivation, critical components of transformative SEL [3].

Emerging technologies also enhance discussion forums, promoting collective intelligence and improving academic performance, particularly among disadvantaged students. These platforms facilitate collaboration and idea sharing, fostering a deeper understanding of subject matter and improving educational outcomes [4]. The potential of emerging technologies to support collaborative learning environments highlights their capability to bridge educational disparities and promote equity in remote learning settings.

6 Lifelong Learning and Adaptation

The contemporary educational landscape increasingly emphasizes lifelong learning, essential for navigating the dynamic job market shaped by rapid technological advancements. This section explores the multifaceted nature of lifelong learning, highlighting its critical role in equipping individuals with the skills needed to adapt to evolving environments. The following subsection will detail how lifelong learning facilitates adaptation in the job market, emphasizing continuous education and personal development as key to resilience and competitiveness.

6.1 The Role of Lifelong Learning in a Changing Job Market

Lifelong learning is crucial for adapting to technological and economic shifts in a rapidly evolving job market. The transition from institutionalized to individualized learning experiences, supported by technology, underscores its importance for personal and professional growth [68, 69]. Participation in lifelong learning is influenced by interrelated factors, necessitating educational policies that align economic outcomes with broader social goals, addressing stagnation amid rapid technological changes [70, 71]. In the AI era, developing competencies in computational thinking, critical thinking, and creativity is essential [72]. AI-driven personalized learning systems, like TrueLearn, provide tailored educational experiences aligned with individual learner profiles [69]. Curiosity-driven learning experiences highlight opportunities for lifelong learning beyond formal education [73]. ICT's role is crucial, necessitating inclusive strategies and exploration of new educational technologies across diverse contexts [74].

6.2 Educational Institutions and Lifelong Learning Support

Educational institutions play a pivotal role in promoting lifelong learning within blended learning environments. They must create frameworks that facilitate continuous education and adapt to learners' evolving needs. Integrating blended learning models is essential for providing flexible, accessible educational opportunities [27]. Categorizing lifelong learning research into conceptual frameworks, abilities, and influencing factors offers a structured understanding of how institutions can enhance initiatives [26]. Aligning institutional policies with national frameworks ensures effective integration of lifelong learning opportunities [70]. Institutions should develop comprehensive training programs for educators in digital pedagogy, exploring innovative assessment methods and fostering a culture of continuous professional development [49]. Identifying effective self-regulated learning (SRL) practices and the role of school leadership in supporting SRL are critical for sustaining lifelong learning initiatives [75]. Developing interactive and engaging teaching methods is vital for enhancing hybrid learning environments [18].

6.3 Digital Tools and Continuous Education

Digital tools are essential for supporting continuous education and lifelong learning, offering platforms and methodologies that enhance adaptability in a changing job market. Tools like Zoom, SLACK, and MIRO facilitate interactive and collaborative learning environments [76]. These platforms

foster digital literacy, crucial for lifelong learning and adapting to job market demands [77]. The integration of advanced technologies like VR and AI aims to improve interactive learning experiences and explore cloud-based solutions for remote access [32]. AI-based learning companions provide personalized feedback, positively influencing learner motivation and metacognitive strategies [72]. Innovative frameworks like the Techno-creative Problem-Solving approach cultivate computational thinking through creative programming, fostering essential skills for lifelong learning [72]. The integration of motivation and fatigue dynamics with skill selection enhances learning experience personalization [60]. Comparing in-situ and post hoc approaches to everyday question-asking reveals the effectiveness of post hoc methods in fostering curiosity and reflection [73]. Ongoing refinement of technological integration in assessments and exploration of new digital tools will continue to shape continuous education [78].

6.4 Challenges and Opportunities in Lifelong Learning

The post-pandemic educational landscape presents challenges and opportunities for lifelong learning, necessitating strategic approaches that leverage technological advancements and innovative pedagogical practices. A primary challenge is fostering autonomous learning practices that empower learners to control their educational journeys [79]. Enhancements to live streaming platforms and hybrid learning models are required to improve remote education experiences [80]. Innovative approaches in fields like engineering underscore the need for logistical advancements in remote learning [81]. E-learning models have shown potential to enhance educational access and quality in rural areas [63]. Future research should prioritize cohesive educational systems that leverage technology while addressing equity and inclusivity [82]. Developing comprehensive training programs for remote education and identifying strategies to maintain community and engagement in online learning environments are critical areas for exploration [15]. Additionally, refining communication strategies, exploring hybrid learning models, and addressing gender representation in hackathon participation can enhance lifelong learning opportunities [83]. Current studies' limitations, particularly the lack of comprehensive evaluations of long-term effectiveness and the need for hands-on experience, present challenges in fostering lifelong learning [84]. Future research should investigate the integration of traditional and digital approaches and their effectiveness in real-life settings [73]. Longitudinal studies are necessary to assess the evolving nature of e-learning and explore technology integration into traditional frameworks [85]. Innovative models that integrate vocational training with broader life skills and explore digital technologies' role in learning can enhance engagement among underrepresented groups [71]. Developing effective support strategies for students with dyslexia in remote learning contexts and examining the long-term effects of such environments are important considerations for future research [86].

7 Addressing the Digital Divide

7.1 Initiatives and Policies to Bridge the Divide

Addressing the digital divide in education requires comprehensive initiatives and policies focused on enhancing access to information and communication technology (ICT) and promoting digital literacy, particularly in marginalized areas. Persistent disparities necessitate targeted policies to improve connectivity and evaluate the socio-economic impacts of these gaps [87]. Establishing a G20 advisory body to refine digital literacy definitions and measurement frameworks is crucial to maintaining relevant assessments of digital skills amidst a changing digital landscape [45]. Innovative analytical methods, like bipartite networks, effectively evaluate digital skills across nations, guiding targeted interventions [56].

Government initiatives to improve ICT access in marginalized regions are vital. Future research should qualitatively analyze the causes of persistent divides and assess the effectiveness of these efforts [88]. Understanding the root causes of digital disparities can lead to more effective policy interventions and resource allocation. Successful initiatives improving technology access, as demonstrated by [89], show how digital tools can empower marginalized communities. The PingER project serves as a framework for monitoring Internet performance, offering insights to guide efforts to bridge the digital divide [90]. Monitoring tools enable policymakers to identify connectivity issues and develop targeted strategies to enhance Internet access. Additionally, using online sampling with

social network reporting can provide faster, cost-effective estimates of offline internet usage, aiding informed policy development [91].

Funding digital infrastructure poses significant challenges, particularly in determining cost responsibilities beyond basic communication expenses. Existing broadband funding models' inefficiencies highlight the need for innovative financial solutions, especially in rural and remote areas where deployment costs are high. Effective funding strategies can integrate ICT across sectors like education, healthcare, and governance, fostering economic opportunities and social inclusion for underserved communities. Leveraging mobile services and tailored applications can create a virtual network economy, connecting these regions to global markets and resources [92, 93, 28, 63]. Overcoming financial and logistical barriers is crucial for expanding digital access and ensuring equitable educational opportunities.

Categorizing research into device access, demographic characteristics, and geographic locations provides a structured approach to understanding the digital divide [21]. Analyzing factors like income level, parental education, and race/ethnicity allows policymakers to design targeted interventions that address diverse communities' specific needs. The survey by [65] further organizes research into stages, highlighting persistent disparities in usage and benefits, especially among lower-educated and older populations.

8 Conclusion

8.1 Future Directions and Research Opportunities

Advancing post-pandemic education necessitates a focus on the efficacy of hybrid learning models across diverse educational landscapes, with particular attention to their impact on students' social development and academic achievement. Investigating transformative social and emotional learning (SEL) within various educational contexts is crucial to refining assessment frameworks and enhancing educational equity. There is also a pressing need to innovate assessment methodologies that protect student privacy while ensuring academic integrity.

The potential of AI-driven educational strategies to promote inclusivity and accommodate diverse learning preferences offers a promising research frontier. Studies should further explore methods to sustain student motivation and engagement in online learning environments, especially during times of crisis. Integrating multiple data sources for nuanced analyses can enhance the understanding of student behavior and engagement patterns, leading to improved educational outcomes.

Research should also prioritize developing stakeholder engagement strategies that align with community values and explore alternative pedagogical approaches that address local needs. Evaluating the effectiveness of hybrid learning models, identifying best practices, and understanding the long-term implications for both students and educators are critical areas for ongoing research. Addressing challenges in the peer review process and fostering trust in peer assessments are essential for enhancing the quality and reliability of educational evaluations.

By focusing on these research priorities, educational institutions can better adapt to the evolving demands of post-pandemic education, creating inclusive, effective, and resilient learning environments that meet the diverse needs of all learners.

References

[1] Emma García and Elaine Weiss. Covid-19 and student performance, equity, and us education policy: Lessons from pre-pandemic research to inform relief, recovery, and rebuilding. *Economic Policy Institute*, 2020.

[2] Jake Mcgrath, Armen Davis, James Curry, Orrie Gartner, Glenn Rodrigues, Seth Spielman, and Daniel Massey. Weather of the dorm wifi ecosystem at the university of colorado boulder for fall semester 2019 to spring semester 2020 a case study of wifi and a campus response to the covid-19 perturbation, 2021.

[3] Robert J Jagers, Deborah Rivas-Drake, and Brittney Williams. Transformative social and emotional learning (sel): Toward sel in service of educational equity and excellence. *Educational Psychologist*, 54(3):162–184, 2019.

[4] Cristian Candia, Alejandra Maldonado-Trapp, Karla Lobos, Fernando Peña, and Carola Bruna. Disadvantaged students increase their academic performance through collective intelligence exposure in emergency remote learning due to covid 19, 2022.

[5] Kendra Gagnon, Brian Young, Teresa Bachman, Thomas Longbottom, Richard Severin, and Michael J Walker. Doctor of physical therapy education in a hybrid learning environment: Reimagining the possibilities and navigating a "new normal". *Physical Therapy*, 100(8):1268–1277, 2020.

[6] Yingwei Cheng and Nicholas Milikich. An analysis of how covid-19 shaped the realm of online gaming and lesson delivery, 2023.

[7] Samantha Robertson, Tonya Nguyen, and Niloufar Salehi. Modeling assumptions clash with the real world: Transparency, equity, and community challenges for student assignment algorithms, 2021.

[8] Nirmalya Thakur, Saumick Pradhan, and Chia Y. Han. Investigating the impact of covid-19 on online learning-based web behavior, 2022.

[9] Bheemeshwar Reddy A, Sunny Jose, and Vaidehi R. Of access and inclusivity digital divide in online education, 2021.

[10] Maxwell Bigman, Yosefa Gilon, Jenny Han, and John C Mitchell. Insights for post-pandemic pedagogy across one cs department, 2022.

[11] Tian Yan and Fang Liu. Sentiment analysis and effect of covid-19 pandemic using college subreddit data, 2023.

[12] Roberto Bacani Figueroa Jr. au2, Florinda Amparo Adarayan Palma Gil, and Hiroshi Taniguchi. Piloting virtual reality photo-based tours among students of a filipino language class: A case of emergency remote teaching in japan, 2023.

[13] Fazlyn Petersen and Bradley Groenewald. Students' engagement in anonymous peer review: Using the open-source sakai platform, 2021.

[14] Luciana Oliveira, Anabela Mesquita, Arminda Sequeira, Adriana Oliveira, and Paulino Silva. Context, input and process as critical elements for successful emergency remote learning, 2021.

[15] Gabriella Oliveira, Jorge Grenha Teixeira, Ana Torres, and Carla Morais. An exploratory study on the emergency remote education experience of higher education students and teachers during the covid-19 pandemic. *British Journal of Educational Technology*, 52(4):1357–1376, 2021.

[16] Alvarez Abel Jr. The phenomenon of learning at a distance through emergency remote teaching amidst the pandemic crisis. *Asian Journal of Distance Education*, 15(1):127–143, 2020.

[17] Qingyun Li, Zihao Li, and Jie Han. A hybrid learning pedagogy for surmounting the challenges of the covid-19 pandemic in the performing arts education. *Education and Information Technologies*, 26(6):7635–7655, 2021.

[18] Junias Robert Gultom, Dadan Sundara, and Medy Desma Fatwara. Pembelajaran hybrid learning model sebagai strategi optimalisasi sistem pembelajaran di era pandemi covid-19 pada perguruan tinggi di jakarta. *Mediastima*, 28(1):11–22, 2022.

[19] Chrysi Rapanta, Luca Botturi, Peter Goodyear, Lourdes Guàrdia, and Marguerite Koole. Balancing technology, pedagogy and the new normal: Post-pandemic challenges for higher education. *Postdigital Science and Education*, 3(3):715–742, 2021.

[20] Sergio Cárdenas, Dulce Lomelí, and Ignacio Ruelas. Covid-19 and post-pandemic educational policies in mexico. what is at stake? *Primary and secondary education during covid-19: disruptions to educational opportunity during a pandemic*, pages 153–175, 2022.

[21] Reale Moore, Dan Vitale, and Nycole Stawinoga. The digital divide and educational equity. *Insights in Education and Work*, pages 1–10, 2018.

[22] Emily Dawson. *Equity, exclusion and everyday science learning: The experiences of minoritised groups*. Routledge, 2019.

[23] Yichen Ma and Dima Nazzal. Exploring educational equity: A machine learning approach to unravel achievement disparities in georgia, 2024.

[24] Kenneth Holstein and Shayan Doroudi. Equity and artificial intelligence in education: Will "aied" amplify or alleviate inequities in education?, 2021.

[25] Mel Ainscow. Inclusion and equity in education: Making sense of global challenges. *Prospects*, 49(3):123–134, 2020.

[26] Win Phyu Thwe and Aniko Kalman. Lifelong learning in the educational setting: A systematic literature review. *The Asia-Pacific Education Researcher*, 33(2):407–417, 2024.

[27] Eva Cendon. Lifelong learning at universities: Future perspectives for teaching and learning. *Journal of New Approaches in Educational Research*, 7(2):81–87, 2018.

[28] Polyxeni Vassilakopoulou and Eli Hustad. Bridging digital divides: A literature review and research agenda for information systems research. *Information Systems Frontiers*, 25(3):955–969, 2023.

[29] Madeleine I. G. Daepp and Scott Counts. The emerging ai divide in the united states, 2024.

[30] Cheryl Flynn, Aritra Guha, Subhabrata Majumdar, Divesh Srivastava, and Zhengyi Zhou. Towards algorithmic fairness in space-time: Filling in black holes, 2022.

[31] Hassan A El-Sabagh. Adaptive e-learning environment based on learning styles and its impact on development students' engagement. *International Journal of Educational Technology in Higher Education*, 18(1):53, 2021.

[32] Claire Palmer, Ben Roullier, Muhammad Aamir, Frank McQuade, Leonardo Stella, and Ashiq Anjum. Digital twinning remote laboratories for online practical learning, 2022.

[33] L. F. S Merchante, Carlos M. Vallez, and Carrie Szczerbik. Towards a low-cost universal access cloud framework to assess stem students, 2024.

[34] Widdy HF Rorimpandey and Hendrikus Midun. Effect of hybrid learning strategy and self-efficacy on learning outcomes. *Journal of Hunan University Natural Sciences*, 48(8), 2021.

[35] Alex Graf. Exploring the role of personalization in adaptive learning environments. *International Journal Software Engineering and Computer Science (IJSECS)*, 3(2):50–56, 2023.

[36] Muhammad Sulistiono. Implementasi hybrid learning menggunakan aplikasi edmodo pada matakuliah metode penelitian kualitatif. *Elementeris: Jurnal Ilmiah Pendidikan Dasar Islam*, 1(1):57–67, 2019.

[37] Arnab Sen Sharma, Mohammad Ruhul Amin, and Muztaba Fuad. Augmenting online classes with an attention tracking tool may improve student engagement, 2022.

[38] Hong Gao, Efe Bozkir, Lisa Hasenbein, Jens-Uwe Hahn, Richard Göllner, and Enkelejda Kasneci. Digital transformations of classrooms in virtual reality, 2021.

[39] David G. Balash, Dongkun Kim, Darikia Shaibekova, Rahel A. Fainchtein, Micah Sherr, and Adam J. Aviv. Examining the examiners: Students' privacy and security perceptions of online proctoring services, 2021.

[40] Hui Han and Silvana Trimi. Cloud computing-based higher education platforms during the covid-19 pandemic, 2022.

[41] Teaching and learning post pande.

[42] Yuliya Nosenko, Maiia V Popel, and Mariya P Shyshkina. The state of the art and perspectives of using adaptive cloud-based learning systems in higher education pedagogical institutions (the scope of ukraine). In *Proceedings of the 6th Workshop on Cloud Technologies in Education (CTE 2018), Kryvyi Rih, Ukraine, December 21, 2018*, number 2433, pages 173–183. CEUR Workshop Proceedings, 2019.

[43] Hamna Hamna and Muh Khaerul Ummah BK. Science literacy in elementary schools: A comparative study of flipped learning and hybrid learning models. *Profesi Pendidikan Dasar*, 9(2):132–147, 2022.

[44] Florence Martin, Yan Chen, Robert L Moore, and Carl D Westine. Systematic review of adaptive learning research designs, context, strategies, and technologies from 2009 to 2018. *Educational Technology Research and Development*, 68(4):1903–1929, 2020.

[45] Krish Chetty, Liu Qigui, Nozibele Gcora, Jaya Josie, Li Wenwei, and Chen Fang. Bridging the digital divide: measuring digital literacy. *Economics*, 12(1):20180023, 2018.

[46] Afif Alfiyanto, Fitri Hidayati, and Muhammad Ghazali. Integration of adaptive learning technology in the context of islamic education in indonesia. In *Proceeding International Seminar and Conference on Islamic Studies (ISCIS)*, number 3, 2024.

[47] Claire Powell and Luke Burns. Digital divide: Mapping the geodemographics of internet accessibility across great britain, 2021.

[48] Jorge Martín-Gutiérrez, Carlos Efrén Mora, Beatriz Añorbe-Díaz, and Antonio González-Marrero. Virtual technologies trends in education. *Eurasia journal of mathematics, science and technology education*, 13(2):469–486, 2017.

[49] M Makhin. Hybrid learning model pembelajaran pada masa pandemi di sd negeri bungurasih waru sidoarjo. *Mudir: Jurnal Manajemen Pendidikan*, 3(2):95–103, 2021.

[50] Annelies Raes, Loulou Detienne, Ine Windey, and Fien Depaepe. A systematic literature review on synchronous hybrid learning: gaps identified. *Learning environments research*, 23:269–290, 2020.

[51] Maria Perez-Ortiz, Erik Novak, Sahan Bulathwela, and John Shawe-Taylor. An ai-based learning companion promoting lifelong learning opportunities for all, 2021.

[52] Harris Bin Munawar and Nikolaos Misirlis. Chatgpt in classrooms: Transforming challenges into opportunities in education, 2024.

[53] Emre Erturk and Derwyn Fail. Information technology in new zealand: Review of emerging social trends, current issues, and policies, 2015.

[54] Janak Adhikari, Anuradha Mathrani, and David Parsons. Bring your own devices classroom: Issues of digital divides in teaching and learning contexts, 2016.

[55] Isabella Hall, Nirmalya Thakur, and Chia Y. Han. Trends in remote learning-based google shopping in the united states due to covid-19, 2022.

[56] Dalila Failli, Bruno Arpino, and Maria Francesca Marino. A finite mixture approach for the analysis of digital skills in finland, italy and bulgaria: the role of socio-economic factors, 2024.

[57] Qin Xie, Ming Li, and Ariunaa Enkhtur. Exploring generative ai policies in higher education: A comparative perspective from china, japan, mongolia, and the usa, 2024.

[58] Paul C Gorski. Poverty and the ideological imperative: A call to unhook from deficit and grit ideology and to strive for structural ideology in teacher education. In *Poverty discourses in teacher education*, pages 5–13. Routledge, 2019.

[59] Sahan Bulathwela, Maria Perez-Ortiz, Emine Yilmaz, and John Shawe-Taylor. Towards an integrative educational recommender for lifelong learners, 2019.

[60] Mingzhen Lu, Tyler Marghetis, and Vicky Chuqiao Yang. Mathematical model bridges disparate timescales of lifelong learning, 2022.

[61] Suzanne Ensmann, Aimee Whiteside, Lina Gomez-Vasquez, and Ronda Sturgill. Connections before curriculum: the role of social presence during covid-19 emergency remote learning for students. *Online Learning*, 25(3):36–56, 2021.

[62] Woong Suh and Seongjin Ahn. Utilizing the metaverse for learner-centered constructivist education in the post-pandemic era: An analysis of elementary school students. *Journal of intelligence*, 10(1):17, 2022.

[63] Shariq Hussain, Zhaoshun Wang, and Sabit Rahim. E-learning services for rural communities, 2013.

[64] Elinor Carmi and Simeon J Yates. What do digital inclusion and data literacy mean today? *Internet Policy Review*, 9(2), 2020.

[65] JAGM Van Dijk. Digital divide: Impact of access. *The international encyclopedia of media effects*, 1:1–11, 2017.

[66] Lamberti Giuseppe, Lopez-Sintas Jordi, and Pandolfo Giuseppe. Tackling cyclicity in causal models with cross-sectional data using a partial least square approach. implication for the sequential model on internet appropriation, 2022.

[67] Tuheen Ahmmed, Afsoon Alidadi, Zichao Zhang, Aizaz U. Chaudhry, and Halim Yanikomeroglu. The digital divide in canada and the role of leo satellites in bridging the gap, 2022.

[68] Kirill Krinkin and Tatiana Berlenko. "flipped" university: Llm-assisted lifelong learning environment, 2024.

[69] Sahan Bulathwela, Maria Perez-Ortiz, Emine Yilmaz, and John Shawe-Taylor. Truelearn: A family of bayesian algorithms to match lifelong learners to open educational resources, 2019.

[70] Ellen Boeren. Understanding adult lifelong learning participation as a layered problem. *Studies in Continuing Education*, 39(2):161–175, 2017.

[71] John Bynner. Whatever happened to lifelong learning? and does it matter. *Journal of the British Academy*, 5:61–89, 2017.

[72] Margarida Romero. Lifelong learning challenges in the era of artificial intelligence: a computational thinking perspective, 2024.

[73] Neha Rani, Sharon L Chu, and Yvette G Williamson. Supporting lifelong learning. *Educational Technology & Society*, 27(2):256–269, 2024.

[74] K Ratheeswari. Information communication technology in education. *Journal of Applied and Advanced research*, 3(1):45–47, 2018.

[75] Daniella Taranto and Michael T Buchanan. Sustaining lifelong learning: A self-regulated learning (srl) approach. *Discourse and Communication for Sustainable Education*, 11(1):5–15, 2020.

[76] Aaron J. Berliner and Jake Hecla. Nuclear history, politics, and futures from (a)toms-to(z)oom: Design and deployment of a remote-learning special-topics course for nuclear engineering education, 2021.

[77] Mehrasa Alizadeh. Exploring engagement and perceived learning outcomes in an immersive flipped learning context, 2024.

[78] Loo Kang Wee. What national examinations reforms should be made and how may technology be leveraged?, 2015.

[79] Cengiz Yurdakul. An investigation of the relationship between autonomous learning and lifelong learning. *International Journal of Educational research review*, 2(1):15–20, 2017.

[80] Zhilong Chen, Hancheng Cao, Yuting Deng, Xuan Gao, Jinghua Piao, Fengli Xu, Yu Zhang, and Yong Li. Learning from home: A mixed-methods analysis of live streaming based remote education experience in chinese colleges during the covid-19 pandemic, 2021.

[81] Savita V. Kendre, Gus. T. Teran, Lauryn Whiteside, Tyler Looney, Ryley Wheelock, Surya Ghai, and Markus P. Nemitz. Printable flexible robots for remote learning, 2022.

[82] Allan Collins and Richard Halverson. *Rethinking education in the age of technology: The digital revolution and schooling in America*. Teachers College Press, 2018.

[83] Kiev Gama, Carlos Zimmerle, and Pedro Rossi. Online hackathons as an engaging tool to promote group work in emergency remote learning, 2021.

[84] Robert Connor Chick, Guy Travis Clifton, Kaitlin M Peace, Brandon W Propper, Diane F Hale, Adnan A Alseidi, and Timothy J Vreeland. Using technology to maintain the education of residents during the covid-19 pandemic. *Journal of surgical education*, 77(4):729–732, 2020.

[85] Rabab Ali Abumalloh, Shahla Asadi, Mehrbakhsh Nilashi, Behrouz Minaei-Bidgoli, Fatima Khan Nayer, Sarminah Samad, Saidatulakmal Mohd, and Othman Ibrahim. The impact of coronavirus pandemic (covid-19) on education: The role of virtual and remote laboratories in education. *Technology in Society*, 67:101728, 2021.

[86] Joanna Zawadka, Aneta Miękisz, Iwona Nowakowska, Joanna Plewko, Magdalena Kochańska, and Ewa Haman. Remote learning among students with and without reading difficulties during the initial stages of the covid-19 pandemic. *Education and Information Technologies*, 26(6):6973–6994, 2021.

[87] Nicolò Gozzi, Niccolò Comini, and Nicola Perra. Bridging the digital divide: Mapping internet connectivity evolution, inequalities, and resilience in six brazilian cities, 2024.

[88] Sergio R. Coria and Luz M. Garcia-Garcia. Digital divide among the states of mexico: a comparison 2010-2020, 2022.

[89] Bernardo Sorj. Information societies and digital divides, 2008.

[90] E. Canessa, H. A. Cerdeira, W. Matthews, and R. L. Cottrell. Monitoring the digital divide, 2003.

[91] Dennis M. Feehan and Curtiss Cobb. Using an online sample to learn about an offline population, 2019.

[92] Naod Duga Jebessa and Henok Getachew Alemayehu. Mobile services and ict4d, to the network economy - bridging the digital divide, ethiopia's case, 2014.

[93] S. K. Nayak, S. B. Thorat, and N. V. Kalyankar. Reaching the unreached a role of ict in sustainable rural development, 2010.

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