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Review

Education in Transition: Adapting and Thriving in a Post-COVID World

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Abstract: The COVID-19 pandemic profoundly disrupted traditional education systems worldwide, prompting a rapid shift to online platforms and the emergence of innovative teaching strategies. This paper critically reviews the extensive body of research on post-COVID-19 education, focusing on the practical and feasible solutions proposed to maintain and enhance educational continuity. The review categorizes and examines studies on various approaches, including simulation-based training, project-based learning, and hybrid models, highlighting their effectiveness during and after the pandemic. Special attention is given to the role of information technology, the challenges faced by educators and students, and the importance of mental health support in the new educational landscape. The findings suggest that while digital tools such as virtual reality and 3D environments show promise, their implementation remains limited, particularly in resource-constrained settings. The study also identifies a significant gap in empirical research on these innovations in the post-pandemic era. Furthermore, the paper highlights the need for systemic changes in curriculum design, educator training, and policy development to address the long-term impacts of the pandemic on education. This review provides a comprehensive overview of the lessons learned from the COVID-19 pandemic, offering insights into how educational institutions can better prepare for future crises.

Keywords: post-COVID-19; higher education; online learning

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1. Introduction

The COVID-19 outbreak has significantly altered the traditional education process [1–5], particularly in developing countries where the lack of resources has had severe consequences [6,7]. The rapid transition to online platforms forced educational institutions to innovate in order to maintain the quality of education, both during the pandemic and in the post-COVID-19 era [7,8]. Numerous innovations have been proposed and evaluated with student samples [9,10]. The impact of COVID-19 has fundamentally changed the perspectives of both students and lecturers regarding the education process [10–12]. For example, leading institutions in English proficiency have started offering at-home tests alongside standardized tests, a practice influenced by the two years of English teaching experience during COVID-19 [11]. A similar conclusion was reached by Chen, Sandford, LaGrone, Charbonneau, Kong and Ragavaloo [10], who suggest that a combination of multiple approaches should define the post-COVID-19 era. This shift represents a strategic change in the administration of English proficiency tests. In the introduction to a special issue on post-COVID-19 higher education, O'Dea and Stern [13] noted that while major studies reported a global digital transformation, there were no significant pedagogical advances—universities simply moved their activities online. Additionally, universities

worldwide implemented similar measures to ensure the continuity of education during COVID-19.

Amid the substantial body of literature published on the topic of education continuity during and after the COVID-19 pandemic, this work seeks to identify and evaluate the practical and feasible solutions that have been proposed. The primary objective of this study is to synthesize the various approaches that can effectively ensure the continuity of education, particularly in the face of future crises that may disrupt traditional educational processes. By critically analyzing the strategies that have been implemented across different contexts, this work aims to provide a comprehensive overview of best practices that can be adapted and applied in similar scenarios. Additionally, the study endeavors to highlight the lessons learned from the COVID-19 pandemic, offering insights into how educational institutions can better prepare for and respond to unforeseen disruptions. In doing so, it seeks to contribute to the ongoing discourse on resilience and adaptability in education, ensuring that future challenges are met with well-informed and strategically sound approaches.

2. Method

The research for this paper was conducted through a systematic review of the relevant literature focused on post-COVID-19 education and its potential future challenges. A comprehensive search was carried out using several major academic databases, including IEEE Xplore, ScienceDirect, Scopus, Springer, and ProQuest. These databases were chosen due to their broad coverage of educational research and their reputation for hosting peer-reviewed journals and conference proceedings across multiple disciplines.

The literature search was conducted in three phases, with each phase addressing different aspects of post-COVID-19 education. The first phase focused on studies conducted during the COVID-19 pandemic, which provided insights into the immediate adaptations made by educational institutions. The second phase examined research conducted after the lockdown, focusing on the longer-term adjustments and trends that emerged. The third phase included studies that were conducted both during and after the pandemic, which offered a longitudinal perspective on how education systems adapted over time.

Keywords used in the search included post-COVID-19 education, online learning, hybrid education models, future of education, longitudinal studies in education, and impact of COVID-19 on teaching. Boolean operators were used to refine the search, such as "AND" to combine concepts like online learning and student performance or mental health, and "OR" to include alternative terms such as remote learning or virtual learning.

To ensure the relevance and quality of the studies included in this review, several selection criteria were applied:

Time Period: Papers were filtered based on the time of study, whether they were conducted pre-, during, or post-COVID-19 lockdown periods. Studies covering multiple phases (pre/during/post) were prioritized for their longitudinal insights;

Relevance to Future Educational Strategies: High preference was given to papers that discussed the future of education, particularly those exploring how education could continue in the event of future crises. Studies that proposed practical, sustainable solutions for maintaining educational continuity were given preference;

Type of Study: A preference was also given to longitudinal studies, as they offered a broader understanding of how educational practices evolved throughout different stages of the pandemic. These studies allowed for a comparison between immediate responses to the crisis and long-term changes in educational strategies;

Focus on Practical Applications: Studies were selected based on their relevance to real-world applications, particularly those that discussed the scalability of educational technologies and strategies in various settings. Studies that evaluated the feasibility of online learning, hybrid models, and simulation-based learning were particularly emphasized.

Once the relevant studies were identified, data extraction focused on key themes such as digital transformation in education, challenges in mental health and student

engagement, and the role of educational technology. Particular attention was paid to studies that highlighted innovations like virtual reality, project-based learning, and serious games as potential solutions for maintaining educational continuity during future crises.

The analysis involved organizing the selected studies into categories based on their focus areas, such as the following:

Mental health and student well-being during online learning;

Educational technology and its role in enhancing learning outcomes;

Teacher and student adaptation to new teaching models, including hybrid and blended learning environments;

Institutional and governmental support for education during the pandemic.

To provide a clear representation of the data, a timeline visualization (Figure 1) was developed, showing the evolution of key themes in post-COVID-19 education research. The frequency of certain terms, such as "online learning", "student engagement", and "digital transformation", was plotted over time to illustrate the shifting focus of research from immediate crisis responses to long-term solutions.

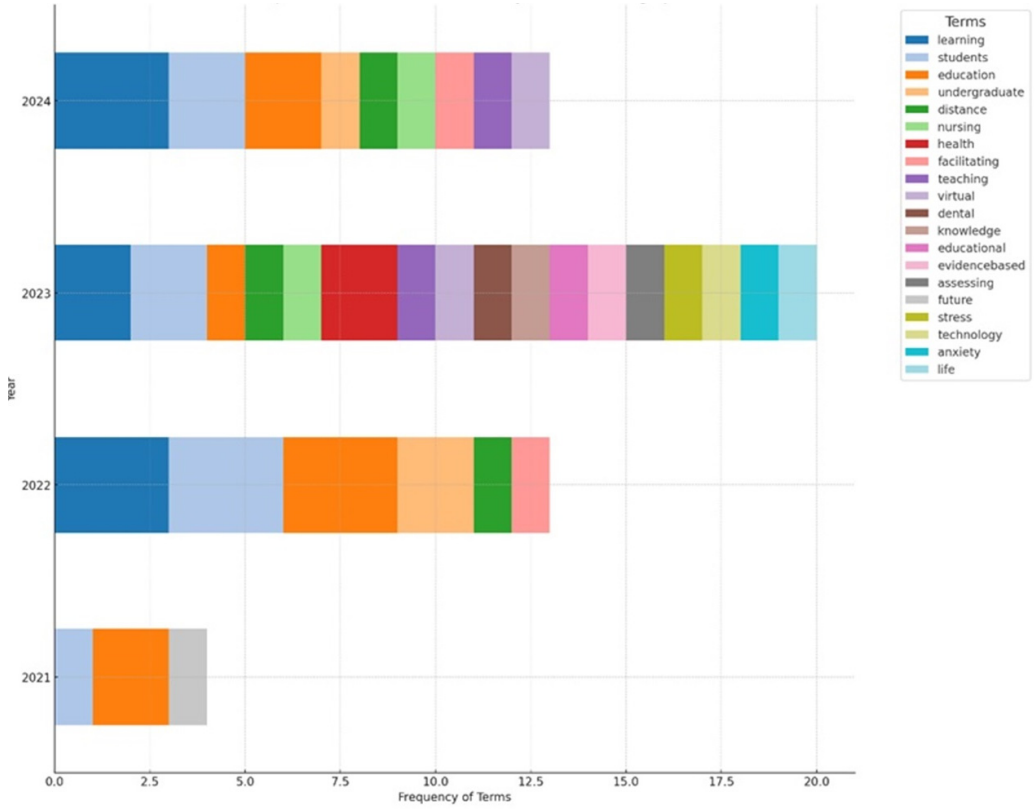

Figure 1. Topics development while timeline progresses.

Additionally, a parallel coordinates plot (Figure 2) was created to show the correlation between different study contexts, countries, and periods (pre-, during, and post-COVID-19). This helped highlight trends in educational research across different regions and timelines.

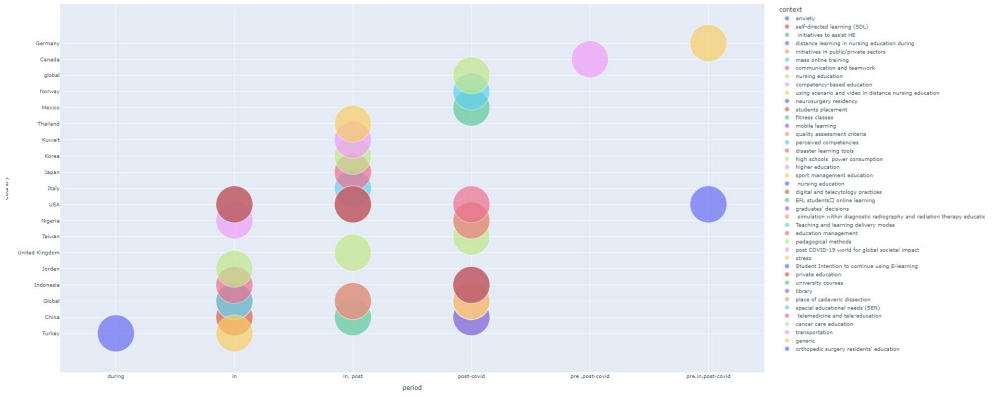

Figure 2. Presentation of studies reviewed in terms of context, period (during COVID-19, pre, or post), country, and author. Note: In refers to studies that report during the COVID-19 in-progress period. In, post refers to studies that covered education during/after COVID-19. Post refers to studies conducted after lockdown due to COVID-19 was officially ended. Pre-post refers to studies that conduct comparison between period before COVID-19 and after. Pre-in-post refers to studies that cover three periods of time: before/during/after COVID-19—a full and interactive version is located at https://drive.google.com/file/d/1EJbyYZxrI3MouA4x4uMyEsZ9auKvP9Yf/view?usp=sharing (accessed on 25 September 2024).

3. Existences Themes

Information technology faced numerous challenges in delivering digital services to education during the COVID-19 pandemic [14]. Throughout the studies reviewed in this work, it was consistently recommended and highlighted as a crucial component of any proposed solutions for post-COVID-19 education and for maintaining educational continuity during the pandemic. A total of 126 studies were reviewed, and to manage this extensive literature, the review was organized into seven main categories based on the common themes observed in the papers.

The first category focused on studies that either reported or proposed solutions specifically for maintaining education during and after the COVID-19 pandemic, with an emphasis on practical, implementable strategies. The second category examined research on ensuring transparent, fair, and high-quality assessment methods during the pandemic, which was a critical concern as traditional examination methods were disrupted. The third category addressed well-being, mental health, and support systems for both students and educators. Recognizing that psychological well-being is just as important as technological solutions, special attention was given to studies proposing strategies for maintaining mental health and providing support during this challenging period.

The fourth category concentrated on the support and training needed for educational staff. As educators had to quickly adapt to new teaching methods and technologies, this section reviewed studies that discussed how best to support and equip them during this transition. The fifth category explored initiatives and solutions put forward by higher-level management, including governments, ministries, and universities. These studies highlighted the role of leadership in ensuring that educational institutions could continue functioning effectively during the pandemic. The sixth category covered other aspects that did not fit neatly into the previous categories but were still important in the broader discussion of education continuity. Lastly, the seventh category delved into discussions about the future, focusing on potential solutions and strategies that could ensure the continuity of education in similar situations that might arise in the future.

Figure 1 is a timeline that visualizes the frequency of the top 20 most common terms in the titles of papers cited in this work after excluding certain specified terms. The number of topics keeps increasing as time progresses from 2021 to 2024. The top topics were related to students (undergraduates), learning, and distance. This provides clues regarding the themes in the reviewed studies.

3.1. Learning and Training

The lockdowns, which resulted in the closure of educational and physical facilities, did not deter researchers from finding innovative approaches to continue delivering quality education. In addition to strategically placing students in campus locations near their residences [15,16], there was a swift transition to online learning, with significant implications for the future of education delivery, particularly in fields like nursing, in a post-COVID-19 world [17].

One of the prominent approaches that emerged was simulation-based training. With the inaccessibility of physical facilities needed for conducting experiments, researchers such as Buyuk, Bermede, Erkoc, Alkls, Lilot and Meco [9] proposed using simulation technology to create virtual environments that closely resemble physical laboratories. Their findings indicated that students' performance after receiving simulation-based training was on par with, and sometimes even superior to, their performance prior to the COVID-19 outbreak.

Additionally, serious games were introduced as a supplementary tool to complement synchronous online classes, ensuring the continuity of pedagogical activities during the pandemic [18]. An extensive study, which involved students from eight different countries, also reported positive outcomes when small groups of students were trained virtually using simulators [19]. These findings suggest that simulation-based methods and serious games could play a crucial role in future educational strategies, particularly in scenarios where physical access to learning facilities is limited.

Another approach explored during the COVID-19 pandemic was project-based blended learning. Anwar et al. [20] proposed this method, where only a small number of students were involved in each project. They argued that this approach is particularly well suited for engineering education. However, their experiment involved a very small sample size, which raises concerns about the generalizability of their findings.

In the context of teaching mathematics during COVID-19, Loza et al. [21] introduced a project-based math course that utilized software to create 3D visualizations of mathematical surfaces. The post-tests from this course indicated that a significant portion of students gained substantial knowledge and performed well on the assessments. However, the limitations identified in Anwar, Hidayat, Yulistiowarno, Budayawan, Zulwisli, Osumah and Ardi [20] study, particularly regarding the small sample size, also apply to the work of Loza, Herrera, Espinosa and Juárez [21].

To address the shortcomings of traditional video conferencing platforms, Estrada et al. [22] proposed and tested a web-based virtual reality (WebVR) tool, suggesting it as a potential future alternative for online conferencing. This innovative approach could revolutionize how virtual meetings and classes are conducted in the future.

A valuable lesson from medical education during the pandemic was reported by Patel et al. [23], who found that virtual-based training and learning are likely to remain relevant in the post-COVID-19 era and could significantly shape the future of education. Additionally, Chang et al. [24] discovered that integrating online game-based learning with the watch–summarize–question strategy was highly effective in a distance learning environment, further highlighting the potential of interactive and engaging learning methods during periods of remote education.

Short learning videos were found to be particularly effective during the COVID-19 pandemic [25]. This finding is promising, and further research by Wijaya and Weinhandl [25] during the post-COVID period, albeit with school students, supports the continued use of this type of educational resource. Another innovative project, reported by Muthmainnah et al. [26], integrated social media with education through a movie-based learning project. This approach highlights the potential of social media in education, a point also emphasized by Carrigan and Jordan [27]. Since this project focused on developing language skills, it could be particularly beneficial in scenarios requiring interaction and communication skill enhancement.

A similar approach was taken by Moralez et al. [28], who conducted a workshop over several days and reported high levels of student satisfaction. Furthermore, Velaora

et al. [29] proposed a combination of various methods, including simulation environments, project-based learning, and asynchronous video lectures. This blend of approaches was designed not only to support students academically but also to provide emotional support during challenging times.

Chen, Sandford, LaGrone, Charbonneau, Kong and Ragavaloo [10] also advocated for the use of multiple approaches. They found that both students and instructors valued face-to-face interactions and preferred a hybrid model that combines in-person, online, and asynchronous course deliveries. Meanwhile, the use of gamification in pedagogy showed promising results in increasing student engagement and enhancing teaching quality, making it a suitable strategy for similar situations in the future [30].

Abdallah and Alriyami [31] concluded that distance learning needs a thorough review before it can fully replace face-to-face education in future lockdown scenarios. They found that many educators agree that the current implementation of distance learning lacks several key functionalities necessary to effectively substitute the traditional teaching paradigm. A significant shortcoming is the reduced level of interaction, which is a common feature of face-to-face learning, especially in collaborative educational settings [32].

In contrast, the e-learning tool CoRad-19, designed specifically for radiology courses in Germany, demonstrated that students slightly enjoyed the experience compared to face-to-face learning, and their performance remained stable [33]. This suggests that, with proper tools and resources tailored to specific needs, distance learning can be effective. However, Lin et al. [34] reported that restructuring courses, particularly by emphasizing a flipped classroom model in medical education, led to better student performance than before the COVID-19 pandemic.

Deuchar [35] provided evidence that international students can manage study and research remotely, which offers insights into the potential shape of post-COVID education. Thompson, Thompson and Sanghrajka [5] assessed various educational approaches in medical colleges and recommended blended learning, emphasizing the importance of keeping the learner in mind and adhering to best practices. Meanwhile, Elshami et al. [36] noted that medical education staff were hesitant to involve students in practical hospital visits during crises like COVID-19, highlighting the need for alternative approaches.

Many studies advocate blended learning as the best alternative to face-to-face education during crises. For example, Fujs, Vrhovec, Zvanut and Vavpotič [2] tested the efficiency of remote conference tools with students from various disciplines, finding no significant performance differences compared to face-to-face approaches. Similarly, a meta-analysis by Gao et al. [37] analyzed online learning versus face-to-face learning in medical education, finding a preference for online learning among students, though the study was limited by a small number of included papers.

Pinchbeck and Heaney [38] focused on student retention through effective tutor engagement in asynchronous online learning, finding it suitable for early higher education levels. Datt and Singh [39] reported that postgraduate students were more adept at utilizing online learning environments compared to undergraduates. In terms of staff engagement, Pérez-Sanagustín et al. [40] emphasized the need for efficient management of online learning and proposed a competency framework to help academic staff deliver quality education during crises like COVID-19.

Innovations like virtual reality, as proposed by Colreavy-Donelly et al. [41], offer promising solutions for blended learning, though cost may limit their widespread adoption. Webinars, widely accepted during the pandemic, were also proposed as an effective tool for continuing education [42–44]. Tlepbergen et al. [45] surveyed non-linguistic specialty students during distance learning and found mixed opinions on its effectiveness, with no systematic process fitting the needs of distance learning during COVID-19. Castillo-Cuesta and Quinonez-Beltran [46] demonstrated that using comics as educational material in English teaching for non-native speakers led to better student performance compared to traditional methods.

Slater et al. [47] found that online communication is as effective as face-to-face interactions for staff engagement. Aksoy et al. [48] investigated the use of case scenarios and skill videos in nursing education, finding positive influences on students' perceptions of the nursing profession, particularly in terms of professional qualifications.

Morrisey et al. [49] examined the impact of COVID-19 on orthopedic surgery residents, finding small but significant decreases in surgical procedures during the peak pandemic year, though overall caseloads increased over time. However, their study focused solely on surgical case volumes without considering other factors affecting resident education during the pandemic. Adetayo [50] investigated the impact of the post-COVID-19 pandemic on library users' education, specifically changes in examination practices and survey methods at Adeleke University, Nigeria. Despite challenges, most students expressed a preference for continuing computer-based testing post-pandemic, though the study relied heavily on descriptive statistics. Suryadinata et al. [51] evaluated the effectiveness of an online interprofessional education (IPE) communication course in Indonesia, finding high student satisfaction, particularly among nursing students.

Giuliani et al. [52] concluded that COVID-19 significantly accelerated the adoption of digital education in cancer care, moving it to a core component of patient education. However, their conclusion was based on a narrative approach. Mohammadi et al. [53] investigated the long-term impact of COVID-19 on neurosurgery residency training in the United States, finding that telemedicine and tele-education became essential components, though they noted limitations in hands-on training and a negative impact on residents' morale.

Qazi et al. [54] conducted a systematic review on mobile learning (M-learning) during COVID-19, finding mixed sentiments with positive aspects like flexibility and accessibility, but also challenges such as technical difficulties and a lack of interaction. These challenges were more pronounced in underdeveloped and developing countries.

Tao et al. [55] compared three physical education teaching modes during the pandemic, finding blended teaching most effective for improving physical fitness indicators. However, the study focused on specific metrics, which may not fully capture the broader impact of the different teaching modes. Chen et al. [56] explored self-directed learning (SDL) in undergraduate ophthalmic education in China during the pandemic, suggesting SDL as a viable alternative when face-to-face learning is not possible.

Chen-Yost et al. [57] compared survey results on digital and tele-cytology practices before and after COVID-19, finding significant increases in the use of tele-cytology, particularly for Rapid On-Site Evaluation (ROSE). Lastly, Choi and Kim [58] conducted a systematic review and meta-analysis on distance learning in nursing education, finding statistically significant positive effects on various aspects of nursing education, though they noted high variability across studies.

3.2. Remote Assessment

This category of studies focuses on maintaining the quality of assessments to match face-to-face standards, with particular attention to issues such as cheating that can undermine assessment integrity. Pavlič et al. [59] proposed a specialized assessment pattern catalog for remote knowledge evaluation. Their tools include the following: (1) Conceptual Design Assessment: Pentathlon, Continuous Testing, and Stepwise Approach. (2) Question Definition and Scheduling: Dress Rehearsal, Statistical Validator, and Expert Validator. (3) Execution and Grading: Randomized Order, Timebox, and Impro League. (4) Communication Assessment: Game Rules and Academic Integrity Appeal. However, these approaches were developed based on feedback from software engineering lecturers, indicating a need for further validation across different departments to ensure generalizability.

In contrast, Pan and Tao [11] revealed that top-ranking institutions are considering the inclusion of at-home online tests alongside traditional standardized exams, informed by their experiences during COVID-19. Hak et al. [60] found that students performed well in online settings during the pandemic but also highlighted the challenges of relying solely on online education in the post-COVID-19 era. Meanwhile, Crick et al. [61] observed no

significant impact of the lockdown on students' performance or socialization, suggesting variability in how students adapt to different learning environments.

Medical education, where knowledge acquisition is critical, has received special attention [62,63]. Ronca et al. [64] evaluated an evidence-based educational program on post-COVID conditions for nursing and radiologic technology students. The program significantly enhanced participants' knowledge of long-term COVID-19 effects, though the study was limited to a single community college, which may not represent experiences elsewhere.

In Korean high schools, Kong et al. [65] reported that academic achievement in the national language remained stable regardless of the learning mode, while mathematics performance declined with increased non-face-to-face education. This finding suggests that face-to-face education may be more essential for subjects that require complex understanding and interaction, such as mathematics.

3.3. Health and Mental Health Support

Revisiting acceptance models, Elnagar et al. [66] found that students who were hesitant about vaccination were more likely to view e-learning as a central feature of the post-COVID-19 period. Health became a significant area of research focus during this time. For example, Zhao et al. [67] studied students' awareness and healthy practices based on family characteristics, finding that students from high-income families or with government-employed parents had better awareness and healthier practices. However, as Zhao, Su and Hu [67] conducted their study exclusively in China, the generalizability of these findings is limited.

Mental health also became a critical concern, with several studies exploring the negative impact of studying from home. Researchers like Chaturvedi et al. [68], Sonbol et al. [69], Drysdale et al. [70], Li and Che [71] discussed various approaches to support students during lockdowns. Zhang et al. [72] specifically examined the relationships between education modes, problematic smartphone use, and related psychological symptoms. They found that students who relied solely on online education experienced higher levels of depressive symptoms, anxiety, and insomnia compared to those who attended face-to-face classes. Similarly, Demirekin and Buyukcavus [73] reported that anxiety and stress were prevalent among students during lockdown.

Schriek et al. [74] investigated the long-term effects of the COVID-19 pandemic on university students' well-being and motivation, finding that emotional exhaustion significantly increased during the pandemic and remained elevated post-pandemic. Student satisfaction initially rose during lockdown but declined in subsequent years, while dropout intentions steadily increased from 2020 to 2023. Despite these findings, enthusiasm among students remained stable throughout the study period. Although the study involved a large sample of 1967 students, it was conducted at a single university in Germany, which may limit its applicability to other populations.

Sancı et al. [75] explored the impact of a video-based COVID-19 pediatric patient education program on reducing anxiety in children admitted to a hospital in Turkey. The study demonstrated that video-based education effectively reduced hospital-related anxiety in children during the pandemic.

Regarding behavior monitoring, Haseeb and Mitra [76] examined changes in travel behavior among post-secondary students in the Greater Toronto and Hamilton Area (GTHA) after the COVID-19 pandemic. They observed a significant shift from public transit and active travel modes to car use. However, the follow-up survey was conducted shortly after COVID-19 restrictions were lifted, which may not fully capture long-term behavioral changes. Additionally, these findings are specific to the GTHA and may not be generalizable to other regions.

Similarly, Peng et al. [77] investigated factors influencing online learning anxiety among Chinese English as a Foreign Language (EFL) students in the post-COVID-19 era. They found that 54.1% of students reported mild to severe anxiety related to online learning,

with rural students experiencing higher anxiety levels than their urban counterparts. Key factors contributing to this anxiety included a lack of learning motivation, separation from instructors and peers, technological challenges, and insufficient two-way communication.

3.4. Teacher/Lecturer/Staff Support

Digital competence among educators and students is an essential element for the future of education [78,79]. Teachers and lecturers require ongoing support and training to prepare for similar situations in the future [3,80–82]. Jocius et al. [83] assessed teacher feedback during and after workshops on virtual computational thinking professional development, highlighting the importance of training to mitigate COVID-19's impact on education. Similarly, Basantes-Andrade, Cabezas-Gonz'alez, Casillas-Martín, Naranjo-Toro and Benavides-Piedra [3] reported the use of nano-MOOCs to enhance digital teaching competencies among lecturers. Pendergast et al. [84] utilized virtual reality to boost lecturers' IT self-efficacy during the pandemic.

Menon et al. [85] focused on supporting lecturers and PhD students by identifying critical research themes in hospitality and tourism post-COVID-19. Norris et al. [86] discussed the Research and Integrity Security Certification (RISC) framework, which could assist academics in maintaining research quality post-pandemic. Giladi et al. [87] explored the professional identity development of lecturers after COVID-19, finding that younger lecturers are more vulnerable and in need of support compared to their senior counterparts. Kline [81] recommended allocating more time and resources to educator preparation programs, while Sun et al. [88] emphasized training lecturers to handle post-COVID-19 challenges.

Selvik and Herrebrøden [89] investigated how transmission control measures during COVID-19 influenced teaching and learning for students with special educational needs in Norwegian schools, finding that smaller class sizes and increased flexibility improved teacher–pupil relationships and allowed for more tailored educational approaches. Latif et al. [90] assessed the rapid upskilling of healthcare workers through mass online training during the pandemic, noting improvements in knowledge and confidence but also reporting high attrition rates, which may affect the generalizability of the results.

Nuryana et al. [91] analyzed trends in research on student stress and mental health during online learning caused by COVID-19, underscoring the need for a post-COVID-19 curriculum that includes mental health support, stress management strategies, and resilience-building activities. Mrayyan et al. [92] examined educator-to-student incivility in online nursing education, finding a low level of reported incivility but moderate occurrences of uncivil behaviors, such as assigning grades without feedback and unclear expectations. Similarly, Roque-Hernandez et al. [93] investigated the impact of perceived instructor presence, interactive tools, and student engagement on satisfaction in hybrid education settings in Mexico. They found that instructor presence and interactive tools significantly enhanced student engagement and satisfaction, with active participation being key to student satisfaction in hybrid learning environments.

3.5. Governmental and Organizational Initiatives

Bortolo et al. [94] investigated the challenges and opportunities related to the sustainable, technological, and innovative transformations in the health, economy, and education sectors driven by the COVID-19 pandemic. The pandemic accelerated the adoption of new technologies, particularly in telemedicine, teleworking, online education, and e-commerce. However, it also underscored the digital divide, particularly in education, where students from lower socio-economic backgrounds faced significant challenges due to a lack of access to necessary technology. While the study focuses on Western contexts, particularly the Hispanic world, this limits the generalizability of the findings to regions with different socio-economic conditions and technological infrastructures. Moreover, the study primarily reviews the existing literature without presenting new empirical data, limiting the depth of analysis and the ability to draw more concrete conclusions.

Similarly, Abbas et al. [95] conducted a systematic review examining global government initiatives and policies that supported higher education during the COVID-19 pandemic, focusing on how these policies facilitated digital transformation and addressed challenges in educational continuity. They found that government policies were crucial in supporting the digital transformation of higher education institutions (HEIs). However, disparities existed between developed and developing countries, with the former being better equipped to handle the transition to digital education. The study lacks detailed case studies that could provide deeper insights into the implementation and outcomes of specific government policies across various countries.

A more specific study by Anggadwita et al. [96] explored changes in educational practices at Indonesian private universities in the post-COVID-19 environment, focusing on the impact of digital transformation and the challenges faced by educators. While the digital transformation presented expected challenges, educators recognized the benefits of blended learning and the need for continuous innovation in teaching methods. The study identified two key determinants of behavioral readiness for change: adaptability and engagement in innovation in educational practice. However, the findings were based on interviews with only 17 educators from private universities in Indonesia, limiting the generalizability to other contexts, such as public universities or institutions in different countries.

3.6. Other Aspects

Several additional directions were identified among the studies, each offering unique insights into the evolving educational landscape. One notable direction involved exploring new design methods for pedagogical strategies. For instance, design thinking was utilized to involve students and lecturers in creating student-centered content for the post-COVID-19 era [97]. Singh [98] advocated for adopting Lean Thinking from the automobile industry into online business education, emphasizing its flexibility in responding to crises. Similarly, Ciano et al. [99] designed a specialized curriculum tailored for online teaching, though they expressed uncertainty about its impact on academic and clinical performance. On the other hand, assessing accreditation virtually due to COVID-19 restrictions was found to be less effective than on-site evaluations [100].

Alhawsawi and Jawhar [101] reported that lecturers were generally receptive to changes in education policies aimed at responding to crises and shaping the future of education, provided there was a robust IT infrastructure, continuous training, and technological support. Botezat et al. [102] found that students exhibited increased entrepreneurial intentions during COVID-19, with a notable rise in enrolment in entrepreneurship education (EE) programs, suggesting that students sought to make productive use of their time during lockdowns. Ratten and Paul [103] also viewed COVID-19 as an opportunity to advance entrepreneurship education. Similarly, Est´ebanez et al. [104] reported higher student participation, learning, and commitment to international cooperation following the pandemic.

Despite numerous pre-pandemic studies proposing models for predicting student performance, it was reported that student performance declined during COVID-19 in China [71]. In response, Kanetaki et al. [105] suggested the need for a new model to address the specific challenges of distance learning due to lockdowns, though the model's accuracy was only 63.7% when tested with mechanical engineering students. Okagbue, Ezeachikulo, Nchekwubemchukwu, Chidiebere, Kosiso, Ouattaraa and Nwigwe [7] focused on competency-based education (CBE) as a potential solution to the challenges faced during the pandemic. They found significant relationships between competency and attitude, as well as perception and willingness, but no significant relationship between competency and perception or digital literacy/skills and willingness. Their findings indicated that the lack of digital literacy and ICT competencies among students and teachers negatively affected their perception and willingness to engage in online distance education.

3.7. Post-COVID-19 Proposals

Post-COVID-19 education has been a major topic of discussion among educators [106]. Five key themes emerged in management education during the pandemic: digital teaching and learning, collaboration and partnership, embracing uncertainty and building resilience, transformation and innovation, and developing an entrepreneurial mindset [106]. There is a strong emphasis on creating blended learning environments that combine the benefits of online and in-person education to meet the diverse needs of students in the post-pandemic world.

Okagbue, Ezeachikulo, Nchekwubemchukwu, Chidiebere, Kosiso, Ouattaraa and Nwigwe [7] stressed the importance of professional training programs for educators to improve ICT competencies and digital literacy. They recommended that education policymakers in Nigeria institutionalize distance online education to safeguard the future of learners and ensure the sustainability of education in the face of future crises. Similarly, Sarker and Shariat Ullah [107] suggested that policymakers and educators develop reliable measurement indicators for new quality assessment criteria, considering the rapid adoption of technology in education. Ermilinda et al. [108] identified habit as the most significant predictor of students' intention to continue using e-learning platforms post-pandemic, with effective lecturer interaction also playing a crucial role.

The integration of multiple teaching modes has gained acceptance among researchers [109]. For instance, there is a call [7] to advocate for competency-based education (CBE) to enhance the skills of students and teachers in a digital learning environment. Sarker and Shariat Ullah [107] recommended future research on integrating generative AI and metaverse technologies into secondary education to further improve quality and accessibility. Al-Gerafi et al. [110] introduced a novel interval-valued fuzzy multi-criteria decision-making framework for selecting pedagogical methods post-COVID, with blended learning emerging as the most preferred method. However, their reliance on expert opinions rather than empirical data may limit the perspective on the effectiveness of these methods.

Practical proposals already implemented during COVID-19 include the continued use of telemedicine in neurosurgery practice, emphasizing the need for a balance with in-person consultations [53]. In medical education, Partner et al. [111] examined the increased use of simulation within diagnostic radiography and radiation therapy education, finding that simulation was widely used across curricula. Toyoda et al. [112] proposed a theoretical framework categorizing disaster learning tools, highlighting the effectiveness of virtual tools in preparedness and evacuation phases, though empirical evidence is lacking.

Alkhaldi et al. [113] explored factors contributing to the perceived success of e-learning among higher education students in Kuwait, finding that instructor response time and attitude did not significantly affect outcomes, suggesting that the role of instructors may be less influential in e-learning. Qazi, Qazi, Naseer, Hasan, Hardaker and Bao [54] emphasized the opportunities presented by mobile learning, such as continued education during the pandemic, reduced costs, and the potential for integrating advanced technologies like AI and VR.

Ratten [114] discussed the need for redefining management education to meet global societal needs, emphasizing responsible management education that integrates ethics, sustainability, and social responsibility. Imran et al. [115] found that blended learning, combining face-to-face and online methods, emerged as the most effective teaching mode post-COVID-19, though the success of different modes varied across countries and disciplines. Chutiphongdech et al. [116] highlighted the need for stronger connections between academia and industry in sport management education in Thailand, emphasizing practical experiences, internships, and collaboration with industry professionals. They also noted that the shift to online learning negatively impacted communication skills, underscoring the need for curriculum changes.

Liao et al. [117] suggested systemic changes to improve working conditions and recognition of nurses to increase enrolment in nursing courses, noting that the pandemic has dramatically changed the job market for graduates. Zhao and Mok [118] found that

the pandemic influenced students' decisions regarding further education and employment, with an increase in students opting for further education at home and a shift toward state sector jobs for greater job security. Figure 2 shows that most studies focused on education during and post-COVID-19, with fewer studies examining the pre-, during, and post-COVID-19 periods. Moreover, a few studies focused on the period before and after COVID-19, such as those by Haseeb and Mitra [76], as well as longitudinal studies [49,74], which covered three periods (before, during, and after the pandemic) in the context of education. Overall, the majority of studies fall within either the COVID-19 or post-COVID-19 periods. The context of these studies was diverse, covering various courses, education modes, mental support, and pedagogy.

Figure 3 demonstrates that the studies conducted in China primarily focused on education in the post-COVID-19 period. However, most of the major studies reviewed were literature reviews with a global scope rather than being specific to any one country. Studies in the USA were more varied, assessing education during COVID-19, during and post-COVID-19, and pre- and post-COVID-19. The majority of the studies reviewed focused on the post-COVID-19 period.

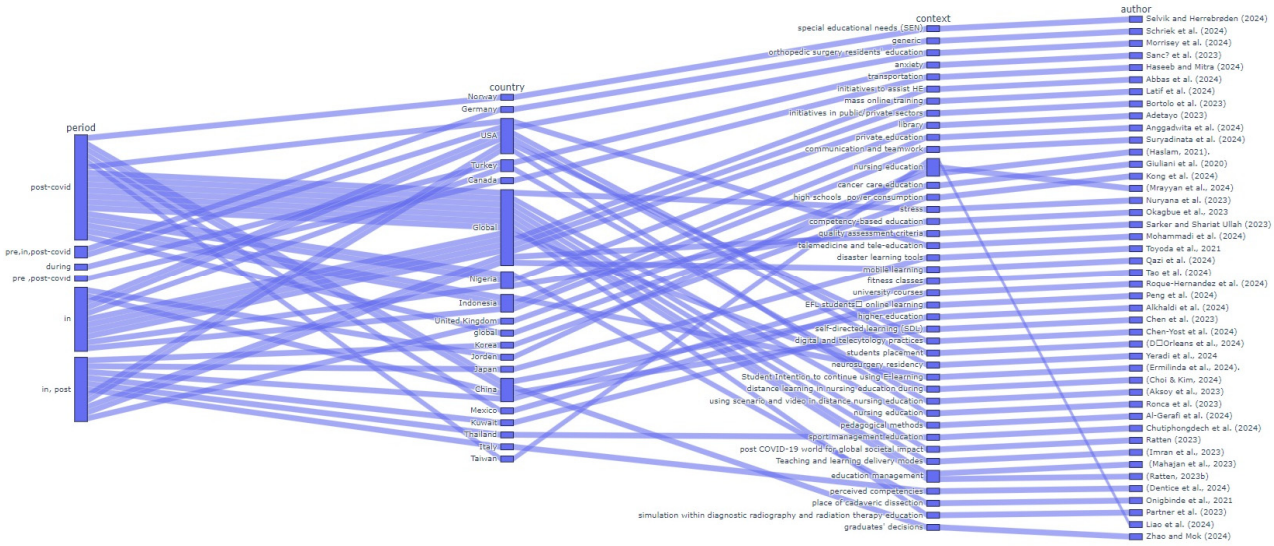

Figure 3. Parallel coordinates plot for period, country, context, and authors. An interaction version is found at https://drive.google.com/file/d/1l-xWbRYFKIjo0mV7b5XMHYITq8D9WYdb/view?usp=sharing (accessed on 25 September 2024).

For a more detailed interaction and links among the studies reviewed in this work, please refer to this page: https://drive.google.com/file/d/1i_ZkePLwSxw2nyPuJdqiHgyoLzknv22F/view?usp=sharing (accessed on 25 September 2024). Finally, a detailed correlation among the studies reviewed is presented in Figure 4.

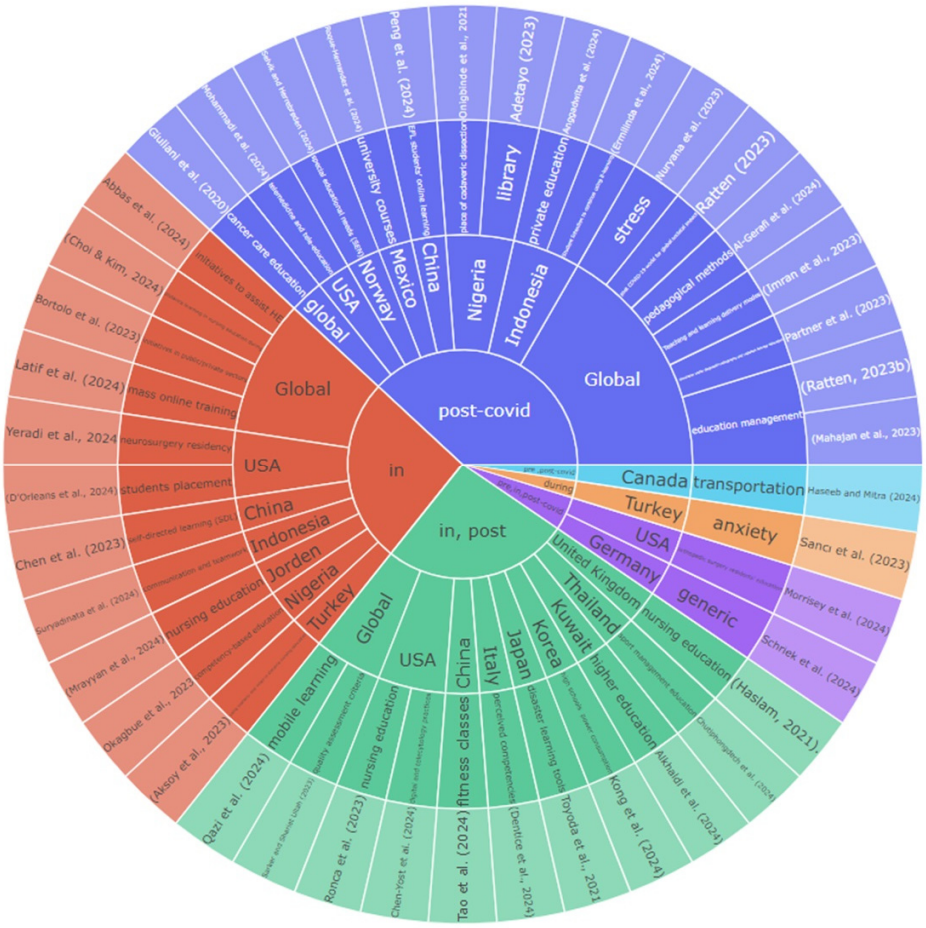

Figure 4. Detailed correlations among studies reviewed. Interactive version is found at https://drive.google.com/file/d/1oZg9BqvdV75z5O36QDwY-opMMx3GRgUO/view?usp=sharing (accessed on 25 September 2024).

4. Discussion

Numerous studies focused on continuing the training and education of medical students during the pandemic, which is understandable given the life-critical nature of medical education. Ensuring that medical students are well prepared before entering hospitals was a primary concern. The second largest group of studies centered on teaching English as a second language (ESL). Compared to these two areas, fewer studies addressed other disciplines.

Medical-related papers emphasized the importance of delivering quality lab experiences through various techniques, including simulation environments, workshops, and involving multiple lecturers and practitioners. In contrast, ESL studies focused on enhancing communication skills, with students showing greater self-discipline and utilizing online resources more despite reduced instructor interaction [34].

Innovative teaching techniques, such as using comics and serious games, showed noticeable improvements in student performance. This suggests that non-traditional approaches may help students overcome challenges presented by unexpected situations like the COVID-19 pandemic. There is also a call to review curricula and incorporate lessons learned from pandemic teaching experiences [4,34]. For instance, applying an integrative clinical approach in virtual medical education was found to be effective, particularly in teaching radiology [119]. This approach was supported by positive feedback from students across Canadian medical schools, although it was only tested in an online setting. The flipped classroom model also demonstrated effectiveness [34]. While recommendations

often lean toward blended learning in medical education, there is little discussion about alternatives if another lockdown were to prevent face-to-face learning [5].

In general, systematic literature reviews, surveys, and interviews were the primary data collection methods used, likely due to their efficiency in rapidly developing insights. The pandemic forced the world to consider distance learning not just as a secondary option but as a robust educational system. Many researchers concluded that a combination of in-person, online, and asynchronous approaches should be considered in post-pandemic education. The pandemic proved the effectiveness of blended and fully online learning, offering a unique opportunity to test alternatives to face-to-face instruction that may not have been fully explored otherwise. Assessing the outcomes of this period will provide valuable insights into the future of education [120].

Manjeese [121] identified four critical success factors for e-learning post-COVID-19: human, technological, environmental, and organizational dimensions, based on assessments from students in developing countries. Karaaslan et al. [122] supported these findings, as detailed in Figure 5. The top recommendation from the studies was for further research (14%), indicating that, even in 2024, solutions for similar future crises remain unclear. Continued research is necessary, though motivation may wane as the immediate crisis fades. The second was instructor's training, which indicates the importance of keeping instructors' skills up to the challenges. Blended and hybrid learning models were the third most recommended approaches, suggesting their current effectiveness.

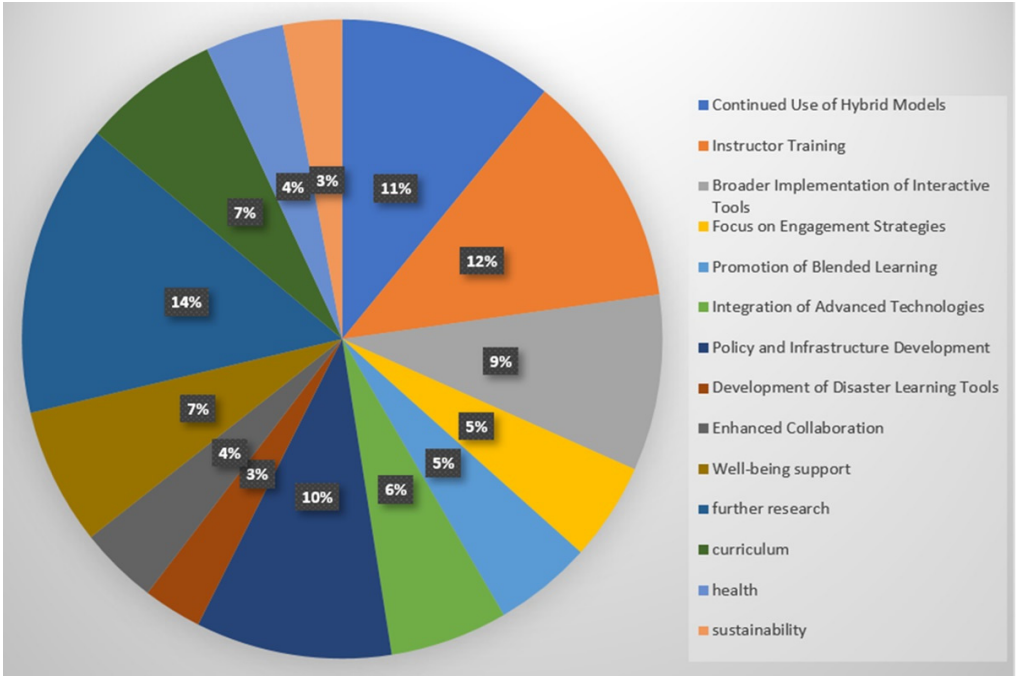

Figure 5. Post-COVID-19 recommendations.

The recommendations for "Continued use of Hybrid models" and "Promotion of Blended Learning" were intentionally separated due to differences in their application, particularly in medical education. Other significant recommendations included investment in interactive tools, policy and infrastructure adjustments, and curriculum updates. A few studies also highlighted the need to develop disaster preparedness tools, reflecting the ongoing risks posed by global warming and instability.

In the context of post-COVID education, many researchers have noted that current online platforms are insufficient for delivering effective teaching. Consequently, they have proposed enhancing teaching quality through the use of virtual reality, 3D environments, and simulations. While these proposals show promise, they have been tested in a limited number of organizations, necessitating further investigation. Positive feedback from those

surveyed suggests the potential success of these approaches, but it is important to note that most of these studies were conducted during the COVID-19 pandemic, with a lack of empirical testing in the post-COVID era.

There has been significant discussion around disease-free physical education environments and hybrid (face-to-face and online) models. Sedano et al. [123] provided several recommendations for post-COVID education, including implementing hybrid education, promoting strategies that integrate technology and health, and investing in safe physical spaces to prevent contagion. Marey et al. [124] introduced and empirically evaluated a hybrid education model, but such suggestions may face serious challenges in developing countries where resources are limited, as reported by Li, Yang, Chen and Li [6], Okagbue, Ezeachikulo, Nchekwubemchukwu, Chidiebere, Kosiso, Ouattaraa and Nwigwe [7], Khan and Abdou [125]. In regions with scarce resources, using alternative channels such as radio and TV has been found appropriate [6].

Although several studies, including those by Moralez, Boren, Lebel, Drennan, Olvera and Thompson [28], Nuryana, Xu, Kurniawan, Sutanti and Makruf [91], Victorino, Bandeira, Painho, Henriques and Coelho [97], Sarker and Shariat Ullah [107], emphasized the importance of redesigning curricula and involving more lecturers and students in the process, these works primarily focused on using design thinking to engage stakeholders. There has been less discussion on the challenges posed by the post-COVID era and fewer concrete suggestions on how to address them within the educational domain.

The majority of studies reviewed in this work attempted to capture the state of education during and after the COVID-19 period. The primary focus was on collecting evidence to determine whether the specific approaches used were effective in delivering quality education. However, there is a significant gap in addressing the broader context, particularly the potential recurrence of such a situation and the feasibility of the proposed solutions in future similar scenarios. In other words, the discussions tend to emphasize short-term perspectives. Moreover, there is a lack of strong arguments regarding viable alternatives to face-to-face education in the event of a similar crisis. Although many studies suggest that a blended learning environment (combining face-to-face and online learning) could enhance access to education and reduce disparities in future crises, this suggestion often overlooks the possibility of crises that could prevent students from physically attending campuses, as happened during COVID-19.

Additionally, the calls to update curricula were often vague, lacking specific guidelines on what aspects need improvement, except for a few studies that addressed assessments. However, studies focused on medical education did report practical solutions, primarily based on remote conferencing, which could be useful in future crises.

In summary, papers that conducted systematic literature reviews and those that proposed frameworks and policies generally agree on the following: integrating advanced technologies such as AI, VR, and emotionally intelligent agents into online learning platforms can enhance engagement and interactivity. They advocate for the continued use of online learning alongside face-to-face education, creating a blended learning environment that leverages the strengths of both approaches. Additionally, they recommend the development of robust ICT infrastructure and supportive policies to address the digital divide and ensure equitable access to online learning, especially in underdeveloped regions. Lastly, they emphasize the need for ongoing training programs for educators and students to improve digital literacy and the effective use of online learning tools. While this consensus is supported by many practical studies, these studies are limited in scope. The advocacy for prioritizing the blended learning mode, observed in many studies as a post-pandemic approach, is due to the fact that it offers a balanced method that combines the benefits of both classroom and online teaching.

On the other hand, it was noted that many students were satisfied with studying remotely and independently, with minimal engagement with classmates and educators. While this approach may not be suitable for all types of education, it could pave the way for a new educational model: student completes courses with minimal interaction with

educators. This is particularly feasible given the vast availability of online resources and powerful generative AI. However, in fields where hands-on practice is essential, such as medical education, alternative approaches like simulation should be further explored.

5. Conclusions

The results of this study confirm that technology will play an essential role in shaping the future of education. Throughout the COVID-19 pandemic, the rapid adoption of online learning methods demonstrated both the resilience and adaptability of educational institutions. However, the study highlighted key challenges that remain unresolved, such as disparities in access to digital tools and the psychological impacts of prolonged screen time on students and educators. Although blended learning models combining in-person and online instruction were favored in many studies, the effectiveness of these approaches varied significantly across different contexts and subjects. For example, while STEM courses adapted well to online simulations, fields requiring hands-on practice, such as medical education, faced more challenges.

The study also highlighted a gap in research focused on long-term strategies for maintaining educational continuity in future crises. While the pandemic offered a unique opportunity to test alternative learning models, the majority of solutions were reactive and focused on immediate needs. Future research should focus on developing robust, scalable educational frameworks that ensure equitable access to learning, particularly in resource-constrained settings. Furthermore, the effectiveness of emerging technologies such as virtual reality (VR) and artificial intelligence (AI) in enhancing learning outcomes requires more empirical evidence, especially in post-pandemic scenarios.

5.1. Limitations

One of the limitations of this study was the reliance on the existing literature, which may not fully capture the rapidly evolving nature of post-pandemic education. The scope of the review was also limited to studies published in major academic databases, potentially overlooking valuable insights from smaller-scale or localized studies. Moreover, while this study primarily focused on higher education, future research should explore the implications of these findings in primary and secondary education settings, where the challenges and solutions may differ significantly.

5.2. Future Directions

Further studies should investigate the long-term impact of blended and hybrid learning models, with a particular focus on underrepresented and vulnerable student populations. Additionally, there is a need for research that explores the integration of emerging technologies, such as AI-driven tutoring systems, into mainstream education. Finally, future studies should prioritize longitudinal research to examine how educational institutions can sustain innovative learning practices in the face of ongoing or future disruptions. This would provide a clearer understanding of the practical applications of current educational innovations and help to develop strategic policies for educational resilience.

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