Building Resilient Educational Systems: The Power of Digital Technologies

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Abstract Recently, the COVID-19 pandemic has posed unprecedented challenges to the education sector, requiring the adoption of digital systems to ensure continuity of learning. This paper aims to examine how digital education systems contribute to enhancing educational resilience. It highlights the role of digital technologies in strengthening academic resilience by enabling adaptive and supportive learning environments. The discussion emphasizes the intricate interplay between diversity, inclusive practices, resilient responses, and the utilization of digital technologies. By exploring the potential of digital systems to enhance educational resilience, this paper contributes to the broader goal of achieving inclusive and equitable quality education, aligned with the United Nations' Sustainable Development Goal 4.

1 Introduction

Resilience is an inspiring construct that has long been associated with child development in the field of education [29, 2]. It is interrelated with studies on vulnerability, protection, survival, and the response to adversity [15].

The term resilience in its Latin etymology comes from *resilio* which means to rebound or to go back. The Royal Spanish Academy (RAE) defines resilience as

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the ability of a material, mechanism or system to recover its original state after experiencing disturbance.

In the context of physics, resilience refers to the ability of a material or system to endure stress, deformation, or damage while retaining its structural integrity and intended functionality. This means that resilient physical entities can withstand external forces and rebound to their initial state or level of performance. Examples of resilient materials include rubber bands, bungee cords, and springs, all capable of stretching and returning to their original shape.

The concept of resilience has been applied in various areas of knowledge. The recurrence of the concept, both in documents and communications from international organizations [34, 33, 23, 21] and recent academic articles examining educational experiences during the COVID-19 pandemic [6, 30, 19, 1] highlight its importance in research.

Unesco proposes that education actors should develop actions to increase prevention, preparation and response to crises, such as alternative educational continuity plans using technologies [34]. Additionally, research in education suggests that resilience can be a product of intentional design [22], and from systemic thinking, resilience has been understood as a capacity that can be developed [7].

Addressing resilience in education is crucial for achieving inclusive and equitable quality education, as outlined in the United Nations' fourth Sustainable Development Goal (SDG) within its 2030 Agenda for Sustainable Development [32]. Inclusion involves creating environments where every individual or group feels welcome, respected, supported, and valued, allowing them to participate fully. Equitable education acknowledges diversity by considering the unique characteristics that differentiate one individual or group from another.

The intricate interplay between diversity, inclusive practices, resilient responses, and the utilization of digital technologies requires a thorough examination. Therefore, this article aims to examine how digital education systems contribute to enhancing the resilience of education.

The rest of this work is organized as follows. Section 2 introduces the concept of resilience across different disciplines. Section 3 presents the components of the concept of resilience in education, analyzing the concept of academic resilience and the resilience of students and teachers. Section 4 delves into the role of digital systems in strengthening academic resilience. Lastly, Section 5 provides concluding remarks and outlines potential areas for future research.

2 Resilience across different disciplines

The concept of resilience originates from the field of Physics and was coined by Michael Rutter in 1972 and 1979 [29] for the study of child development. Subsequently, it was adopted in the field of social sciences, particularly in social work research and socio-educational policies. However, its application extends across numerous disciplines.

In psychology, resilience has long been associated with the understanding of child development. It explores how individuals can overcome traumatic experiences and setbacks, emerging more robust and more resilient on the other side. The study of resilience delves into the protective factors, coping mechanisms, and support systems that enable people to navigate difficulties and achieve positive outcomes.

In the field of engineering and materials science, resilience takes on a physical dimension. It refers to the ability of materials, mechanisms, and systems to withstand stress, deformation, or damage while retaining their structural integrity and functionality.

Ecology unveils yet another facet of resilience, focusing on the ability of ecosystems to absorb disturbances, adapt, and maintain their essential functions. In the face of environmental changes and disruptions, resilient ecosystems demonstrate the capacity to regenerate, sustain biodiversity, and provide critical ecosystem services.

Despite the differences in how resilience is applied in these diverse disciplines, the core concept remains strikingly similar. Across structural engineering, social sciences, and ecology, resilience shares the common essence of withstanding challenges, adapting to changes, and preserving crucial functions. Analyzing resilience in these varied fields provides valuable insights that can enrich our understanding and application of resilience in educational systems.

2.1 Resilience in Structural Engineering

Within the field of structural engineering, the study of resilience primarily focuses on constructing anti-seismic houses [5, 9]. These studies highlight the examination of four crucial properties known as the ”4Rs” for resilience analysis:

- Robustness: refers to the strength and ability of elements, systems, and other units of analysis to withstand a given level of stress or demand without experiencing degradation or loss of function. In anti-seismic construction, robustness is of paramount importance to ensure the integrity and stability of buildings during seismic events.
- Redundancy: addresses the presence and extent of substitutable elements, systems, or other units of analysis within a structure. It involves having backup components or alternative mechanisms that can fulfil functional requirements in case of disruption, degradation, or loss of functionality. Structures can maintain their essential functions by incorporating redundancy even if certain elements become compromised during a seismic event.
- Resourcefulness: reflects the capacity of structural engineers and stakeholders to identify potential problems, establish priorities, and mobilize resources in the face of conditions that may threaten to disrupt elements, systems, or other units of analysis. This involves strategic planning, coordination, and decision-making to mitigate risks and effectively ensure structures' resilience.
- Rapidity: refers to the capacity to meet priorities and achieve goals in a timely manner. Rapid response and recovery are crucial in minimizing the impact of

the event, ensuring the safety of occupants, and restoring functionality to affected structures. It involves efficient communication, well-defined emergency protocols, and the availability of necessary resources.

Additionally, the study of resilience explores integrating smart technologies, sensors, and real-time monitoring systems to enhance structures' adaptive capabilities and response mechanisms.

2.2 Resilience in social systems

Resilience is the ability of a social system to absorb disruptions and reorganize itself while undergoing changes in such a way that it still maintains essentially the same function, structure, identity, and feedback [36]

Furthermore, social systems exhibit diversity and redundancy. They encompass a variety of components, social actors, and institutional arrangements. This diversity provides alternative pathways for adaptation and enables the system to function effectively even when certain components or relationships are disrupted. Redundancy ensures that multiple actors or resources are available to fulfil critical functions, reducing the vulnerability of the system to single-point failures.

Connectivity also plays a vital role in the resilience of social systems. Interactions and linkages between different components within the system enable the flow of information, resources, and feedback loops. These connections allow for the diffusion of knowledge, cooperation, and the exchange of resources, which enhances the system's capacity to respond and adapt to changes.

The emphasis in studying resilience in social systems lies in understanding the dynamics of the system. The focus is on comprehending how the system operates, adapts, and responds to internal and external influences. By examining social components' interactions, feedback loops, and interconnectedness, researchers aim to uncover the underlying mechanisms contributing to the system's ability to withstand disruptions, recover from challenges, and maintain its essential functions. Works such as Fath *et al.*[14] and Cote and Nightingale [10] integrate the study of resilience in social systems with the concept of resilience in ecological systems. They highlight the transformative processes that occur during times of crisis, chaos, confusion, and innovation as the phases that foster resilience.

Social resilience in the face of disasters and crises involves a cyclical process that encompasses the following four key phases: mitigation, preparation, response, and recovery [12].

- Mitigation: focuses on strengthening the community's capacity to manage future disasters effectively. This involves taking proactive measures, such as constructing climate-responsive housing, implementing land-use planning strategies, and promoting sustainable practices.
- Preparation: involves anticipating emergencies and developing a robust emergency response system. This includes establishing early warning systems, creat-

ing response plans, stockpiling necessary resources, and conducting drills and training to enhance preparedness.
- Response: entails immediate actions taken during and immediately after a disaster. It involves activating emergency protocols, mobilizing resources, and providing emergency relief and assistance to affected individuals and communities. Effective response measures include search and rescue operations, medical aid, and the establishment of temporary shelters and distribution centers.
- Recovery: focuses on assessing the damage, initiating repairs, and facilitating the recovery of the community. This phase involves conducting damage assessments, securing reconstruction funding, supporting affected individuals and businesses, and restoring critical infrastructure and services.

This resilience cycle at the social and community level involves three distinct levels that can be addressed to enhance resilience [12]. Firstly, the individual level focuses on building personal resilience among community members. This involves promoting psychological well-being, providing access to resources and support systems, and enhancing coping skills to navigate challenges and adversities effectively. By empowering individuals to develop their own resilience, communities can establish a strong foundation for overall resilience. Secondly, the community level fosters collective resilience by establishing social networks, community organizations, and collaborative decision-making processes. Building social cohesion and fostering a sense of belonging within the community encourages mutual support, cooperation, and the sharing of resources. Lastly, the systemic level recognizes the importance of addressing structural and systemic factors influencing community resilience. This involves analyzing and addressing social inequalities, economic disparities, and environmental vulnerabilities that can hinder a community's ability to withstand and recover from shocks and stressors.

As an example case, we analyze the city of Montevideo, the capital of Uruguay during the COVID-19 pandemic. Like many countries, the government had to implement containment measures to prevent the spread of the virus. The economic situation of a large part of the population was affected. Between March and July 2020, more than 25 per cent of workers in the formal private sector was sent to unemployment insurance. As a result of this situation, the solidarity of the Uruguayans emerged to face the crisis and together with it, a large number of soup kitchens and picnic areas arose. In a study carried out by a team from the Faculty of Social Sciences of the University of the Republic, more than 60 per cent do not have any state support [27]. Since most of the popular pots and picnic areas in Uruguay do not have state aid but solidarity, it was considered a social resilience act. However, as [27] mentions, these seemingly spontaneous initiatives build on existing networks and recreate them. Neighbourhood social militants of many years and many struggles retake leadership. Collectives or communities of different types of affinity (political, sports, religious) with decades of neighbourhood work take action, although not necessarily structured and permanent. Other elements that stand out in the work of [27] is the capacity for collaboration between these community experiences with more structured and traditional social organizations, with more significant resources, such as worker unions and the existence of meeting spaces that allow collaboration. How-

ever, collaborating in these meeting spaces is not easy since it supposes the existence of different "modes" can only be strengthened if they are reciprocally respected.

Olssen *et al.* [24] highlights the problems of using resilience as a universal and unifying concept in the social sciences. The conclusions drawn are that there are differences in resilience definitions, a lack of compatibility between natural and social sciences, and the ambition to unify resilience beyond natural sciences is counterproductive. Additionally, caution is advised regarding the risk of resilience being used in a depoliticizing or naturalizing manner by political actors. For fruitful interdisciplinary collaboration, it is suggested to prioritize pluralism over radical unification. The article finishes by stating that in order to foster productive interdisciplinary collaboration, such as problem-solving approaches, embracing pluralism is not only sufficient but also potentially more favourable.

3 Resilience in Education

Resilience in education refers to the ability of individuals and educational organizations to face and overcome challenges, adversities, and changes in the educational context. Its study is usually approached from two perspectives: individual resilience and organizational or system resilience. In this section, we briefly introduce these two perspectives.

3.1 Student and Teacher Resilience

Individual resilience in education refers to the capacity of students and teachers to adapt, persist, and succeed academically despite difficulties. It involves developing socio-emotional skills such as self-confidence, self-regulation, perseverance, and the ability to cope with academic stress and pressure.

Resilient students have the ability to bounce back from failures and setbacks, learn from them, and move forward. They can also leverage available resources, seek support, and maintain motivation and commitment to learning over time. Students' resilience, also known as "academic resilience," has been extensively studied [20, 25, 17, 11, 4, 16]. These works mainly examine the academic resilience of students from psychological and social perspectives. They highlight the leadership capacity of resilient students and their ability to work in a network, build valuable interpersonal relationships, and establish social networks. Additionally, their ability to adhere to beliefs, principles, or values is observed as a determining factor necessary to persevere and succeed in academic goals. However, since the Covid-19 pandemic, studies in this area have embraced a broader conceptualization of academic resilience that recognizes significant concerns regarding physical well-being and mental health in student populations.

In the same way, as with the study of student resilience, the work on teacher resilience increased due to the Covid-19 pandemic [28, 37, 31, 35, 19].

Teacher resilience encompasses various dimensions that contribute to their overall well-being and ability to navigate challenges. Similar to student resilience, four possible dimensions of teacher resilience can be identified: profession-related, emotional, motivational, and social.

The profession-related dimension of teacher resilience acknowledges the specific demands and responsibilities that teachers face within their educational roles. It encompasses aspects such as their professional identity, sense of efficacy, and belief in their ability to achieve desired outcomes for their students. This dimension recognizes the importance of teachers' self-perception and their confidence in positively impacting student learning. The emotional dimension of teacher resilience focuses on the emotional well-being of educators. It involves their capacity to regulate and manage their emotions in the face of stressors and challenges. This dimension acknowledges that teaching can be emotionally demanding and highlights the significance of emotional intelligence and self-care practices in maintaining overall well-being. The motivational dimension of teacher resilience pertains to teachers' intrinsic motivation and passion for their profession. It encompasses their drive to continually improve and adapt their instructional practices and their ability to find purpose and fulfilment in their work. This dimension recognizes the importance of fostering a sense of autonomy, mastery, and purpose in teaching to sustain long-term resilience. Lastly, the social dimension of teacher resilience emphasizes the significance of social support and positive relationships within the educational context. It acknowledges that teachers thrive in environments where collaboration, collegiality, and effective communication are fostered. This dimension highlights the importance of building supportive networks, seeking mentorship opportunities, and engaging in collaborative professional learning communities.

In measuring teacher well-being, Folk *et al*. [13] highlight four essential concepts: self-efficacy, work and emotional stress, job satisfaction, and social-emotional competence. Self-efficacy refers to teachers' belief in their ability to achieve desired outcomes for their students, which is closely linked to their professional resilience. Work stress and wear recognize the potential challenges and demands that teachers may face, underscoring the importance of managing stressors and maintaining a healthy work-life balance. Job satisfaction reflects the level of fulfilment and contentment teachers experience in their roles, as it significantly influences their overall well-being. Lastly, social-emotional competence recognizes the importance of teachers' ability to effectively navigate and manage their emotions and build positive relationships with students and colleagues. Promoting teacher resilience is crucial not only for their own well-being but also for creating optimal learning environments and promoting the resilience of students.

Moreover, according to Wang [37], one of the major challenges that teachers encountered during the COVID-19 pandemic was the sudden need to transition their courses online without having sufficient mastery of the necessary technology. This situation resulted in teachers experiencing technostress, which added to the difficulties they faced. Consequently, it is crucial to ensure that faculty members are equipped

with contemporary digital skills to address such situations effectively. By providing teachers with the necessary training and resources, they can develop the competence and confidence required to navigate digital platforms and tools seamlessly. This preparation will not only enable them to adapt to unexpected circumstances but also enhance their overall teaching effectiveness in an increasingly digital era.

3.2 Educational Systems Resilience

According to UNESCO, education resilience refers to 'the capacity of children, families, communities and systems to resist, adapt and recover from shocks and stresses' [33]. As Jacobson et al. [18] and Pickernell [26] pointed out, educational systems are complex systems because they are made up of a set of actors (students, teachers, directors of institutions, parents, society, the economic system, the health system) where all these actors interact together and can create new and sometimes uncertain results. Since they all affect everyone, it is considered a complex system. In complex systems, different actors hold diverse perspectives on what defines an ideal solution, leading to a complex challenge. Achieving a viable solution requires the active participation of all stakeholders, fostering open dialogue, and collectively arriving at a solution. It is crucial to acknowledge and recognize the diverse capabilities that each group of actors brings to the table. The process begins by creating a collaborative environment where all voices are heard and valued. This involves establishing effective communication channels and platforms that facilitate meaningful interactions among the actors. By encouraging active participation and fostering a culture of respect and inclusivity, the barriers to collaboration can be overcome. Furthermore, it is essential to understand and appreciate the different perspectives and expertise that each actor contributes. Each group may bring unique insights, experiences, and knowledge that can enrich the problem-solving process. By recognizing and leveraging these diverse capacities, a more comprehensive understanding of the complex system can be achieved.

Building resilience in complex systems involves navigating the dynamic nature of the system and progressing through several key phases[8]. These phases are essential for understanding and addressing the challenges presented by complex systems while fostering resilience: Detection, Prioritization, and Reconfiguration.

Detection involves recognizing and identifying potential threats, vulnerabilities, or disruptions that could impact the system's stability and functionality. This phase entails implementing robust monitoring mechanisms, data analysis, and early warning systems to identify signs of stress or disturbances. By promptly detecting potential risks, stakeholders can initiate timely responses and interventions. Once potential risks or disruptions are detected, the next phase is prioritization. This involves assessing and ranking the identified risks based on their severity and potential impact on the system. Prioritization requires careful analysis, considering the consequences of each risk on different aspects of the system, such as its operations, resources, or stakeholders. By prioritizing risks, resources and efforts can be directed towards

addressing the most significant threats first, ensuring a more efficient allocation of resources. The reconfiguration phase focuses on adapting and adjusting the system in response to identified risks and priorities. It involves evaluating changes in the system's structure, processes, and strategies to enhance its resilience. This may include modifying operational procedures, updating policies, investing in new technologies, or developing alternative pathways. Reconfiguration aims to strengthen the system's ability to withstand and recover from disruptions, improving its adaptive capacity and ensuring its continued functionality.

These three phases are interconnected and iterative, forming a continuous cycle of resilience-building within the system. Detection allows stakeholders to identify potential risks, which are then prioritized to guide decision-making and resource allocation. Based on the priorities, the system undergoes reconfiguration to enhance its resilience. However, as the system evolves and new risks emerge, the cycle restarts with detection, followed by revised prioritization and reconfiguration.

By systematically progressing through these phases, stakeholders can proactively identify, address, and mitigate risks, enhancing the system's resilience and its ability to withstand and recover from disturbances.

In this process, a crucial moment arises when determining the appropriate time to halt these processes and declare, "Let's consolidate this new process and secure the necessary resources." This decision-making entails leveraging the available resources and those accessible through networks, identifying the timely moment to acquire additional resources, and obtaining them to successfully consolidate the change. Implementing this process effectively involves reorganizing and integrating new resources that may not currently be in existence, such as new teachers or advanced technologies [26].

However, as highlighted by the recent study conducted by Borazon and Chuang [3], further research in this field is imperative. Current studies on educational resilience predominantly concentrate on the resilience of students and educators, overlooking other important aspects. Therefore, there is a need for additional research to obtain a comprehensive understanding of resilience within the broader educational context. Expanding the scope of research to encompass various dimensions, such as institutional, systemic, and community resilience, will enable a more nuanced and holistic perspective. By considering these additional facets, policymakers and stakeholders can develop more effective strategies and interventions to address the multifaceted challenges faced by educational systems.

4 The Role of Digital Systems in Education Resilience

We have identified various perspectives in the literature regarding the discussion of the role of digital systems in education resilience. We have organized this discussion into five axes, each of which is presented below. But initially, it seems fair to acknowledge the fact that the integration of technology into education has revolutionized learning processes, offering adaptability and continuity in the face of

unforeseen events, such as the COVID-19 pandemic. Digital tools and platforms have proven instrumental in enabling seamless transitions to remote and online learning, ensuring educational activities persist despite physical constraints. However, with these advantages came challenges, particularly in the realm of digital safety and literacy. To address these issues, at present, it becomes essential to focus on fostering digital resilience in students, educators, and the education system as a whole. This new discussion explores the dark side of technology, highlighting the need for digital resilience and how it can empower individuals to navigate and overcome the potential pitfalls of the digital world.

The Dark Side of Technology: Unveiling the Digital Threats As digital technology infiltrates educational systems, it brings along an array of challenges that impact students and educators alike. Digital safety, a key component of teachers' digital literacy, encompasses issues ranging from mental and physical health to social aspects and technical concerns associated with the use of information and communication technologies. The rise of electronic threats (e-threats) poses serious problems, including cyberbullying, hate speech, image manipulation, and the spread of misinformation through echo chambers. These threats jeopardize the well-being of individuals and the dynamics of digital communities, demanding a proactive approach to address them effectively.

The Role of Digital Literacy in Building Resilience Addressing the challenges posed by digital threats necessitates a comprehensive understanding of digital literacy. Modern schools must equip students and educators to navigate the digital world safely and responsibly. Digital literacy, therefore, should be considered an integrating construct that prepares individuals to deal with the risks and uncertainties of the digital landscape. It empowers learners to critically evaluate information, recognize biases, and discern legitimate sources from misinformation. Furthermore, digital literacy enables educators to support students in developing the necessary skills and mindset to protect their well-being and foster positive online relationships.

Fostering Digital Resilience: A Vital Educational Imperative Digital resilience emerges as a solution to combat the negative consequences of technology integration in education. It goes beyond mere technical proficiency; it entails a proactive approach to address digital risks and challenges effectively. Building digital resilience involves cultivating essential skills, such as media literacy, critical thinking, and emotional intelligence. By encouraging students and educators to confront online negativity, misinformation, and manipulation, educational institutions empower them to maintain a positive and informed online presence.

Integrating Digital Resilience in Educational Curricula To truly promote digital resilience, educational institutions must prioritize it within their curricula and pedagogical approaches. Infusing digital resilience education throughout various subjects and age levels can help instil a deep understanding of digital safety and ethics. Interactive workshops, real-life case studies, and open discussions on digital dilemmas can equip students with practical skills to handle digital challenges effectively. Moreover, teachers must be trained to become role models in digital resilience, demonstrating appropriate online behaviour and guiding their students through the complexities of the digital world.

Collaboration and Community Engagement: Strengthening Digital Resilience Building digital resilience requires a collaborative effort between educational institutions, families, and the broader community. Parents and caregivers play a critical role in supporting students' digital learning journeys, ensuring they comprehend the importance of digital safety and ethical behaviour. Additionally, partnerships with industry experts, non-profit organizations, and governmental bodies can enrich digital resilience initiatives with up-to-date knowledge and resources. Moreover, the use of analytics and insights from digital systems can guide the development of targeted support mechanisms, ensuring every learner receives the necessary assistance to thrive academically.

Embracing digital technology in education is essential for fostering adaptability and continuity. Nevertheless, it comes with its share of challenges, including digital threats that require proactive action. Cultivating digital resilience is crucial for empowering students and educators to navigate the darker side of technology effectively. By integrating digital resilience education into curricula and promoting collaboration with families and the community, educational institutions can create a safer, inclusive, and empowered digital learning environment for all.

5 Conclusions and Future Work

After reviewing various disciplinary perspectives and striving to embrace a pluralistic viewpoint, two main approaches come to light: structural and dynamic (Table 1). When considering decision-making moments, these approaches seem to offer distinct goals: design and management. Design would involve contemplating the characteristics of the system, including the territory it operates within, the networks it is connected to, and the academic communities it engages. Conversely, management could entail on-the-spot decision-making, resource mobilization, and the activation of assets at different levels of governance. This process is informed by accessing, processing, and interpreting current data. Design would emphasize robustness and redundancy, and management would prioritize rapidity and resourcefulness. In

essence, designing resilient structures should target mitigation, preparedness, and formative actions, whereas effective management requires the ability to detect, prioritize, and reconfigure in order to respond and recover swiftly. In conclusion, by understanding and incorporating both structural and dynamic perspectives, organizations can better navigate complex challenges and foster a more adaptable and resilient environment.

	STRUCTURAL PERSPECTIVE	DYNAMIC PERSPECTIVE
Goal	Design	Management
Components	Territory, institutions involved, networks involved, academic and professional communities, pedagogical models, infrastructure, face-to-face and digital environments, modes of delivery, methodology and didactics, teacher and student support systems	Governance, decision-making, data use: access, manipulation, interpretation, management strategies, educational resources: access, curation, adaptation, remixing, class management and tutoring actions
Qualities to develop	Robustness Redundancy	Rapidity Resourcefulness
Actions	Design, plan, develop, prepare, train, prevent	Detect, prioritize, reconfigure, respond, recover, decide "on the spot"

Table 1 Two perspectives of the resiliency of educational systems.

As for educational resilience, the focus has been mainly on the resilience of students and educators, overlooking other crucial aspects. Therefore, there is a pressing need for further research to gain a fuller understanding of resilience within the educational context as a whole. By broadening the scope of the research, which encompasses various dimensions such as institutional, systemic and community resilience, a more nuanced and holistic perspective can be obtained. This research should embrace a pluralistic view, which would require not only methodological rigour but also a predisposition to engage in interdisciplinary dialogue. This expanded research would enable policymakers, educators, and stakeholders to develop more effective strategies and interventions that address the multifaceted challenges facing education systems. Therefore, future research efforts should aim to explore and unravel the intricate dynamics of resilience within the broader educational landscape, ensuring a comprehensive approach encompassing all relevant factors.

By understanding and leveraging the opportunities presented by digital technologies, educational institutions can enhance their capacity to respond effectively to challenges, promote equitable educational experiences, and facilitate sustainable development in the education sector.

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