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Digital Resilience in Higher Education in Yemen:

Aden University During the COVID-19 Pandemic, A Case Study

Mohammed Abobakr

Yemen

MARIAM AL-SHAFEI

FELLOWSHIP ON TECHNOLOGY AND HUMAN RIGHTS

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SMEX is a nonprofit dedicated to safeguarding human rights in digital spaces across West Asia and North Africa. We advocate for safe and uncensored access to the internet, mobile services, and networked spaces for people in the region and the diaspora. Recognizing the inseparable link between digital rights and human rights, SMEX focuses on the impact of technology on fundamental freedoms.

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Executive Summary

This study explores the status of digital resilience in Yemen's higher education system amid the COVID-19 pandemic. Focusing on Aden University as a case study, the research aims to identify challenges and opportunities for building and implementing an resilient digital learning environment to ensure educational continuity, and to evaluate to what extent official measures and adaptations -made by educational institutions- were efficient. A mixed-methods approach was employed, combining quantitative data from surveys of 40 students with qualitative insights from interviews with key faculty members, administrators, and students. The study is grounded in Resilience Theory, the Technology Acceptance Model (TAM), and Diffusion of Innovations (DOI) Theory, providing a multifaceted lens to examine institutional adaptability, technology acceptance, and the spread of innovations within the university.

Findings reveal significant barriers to resilient digital learning environments implementation, including technical challenges like unreliable electricity, poor internet connectivity, faculty resistance due to technical skills gaps, and cultural and socioeconomic factors such as economic hardships and traditional educational norms. Only 5 out of 40 surveyed students had reliable internet access for more than six hours a day, and frequent power outages severely hindered both students and faculty.

Despite these challenges, the study identifies innovative adaptations that illustrate the potential for building digital resilience. The research underscores the critical role of infrastructure development, faculty training, and collaborative efforts among stakeholders—including government bodies, international organizations, university administration, faculty, students, and the private sector—in enhancing digital resilience. Practical recommendations include conducting retrospective analyses of pandemic responses, developing comprehensive emergency plans, promoting lean operational models, and fostering collective responsibility.

Introduction

Higher education systems worldwide have increasingly recognized the importance of digital learning as a means to ensure educational continuity, especially during periods of disruption. Over the past decade, concepts like "digital resilience"—the ability of institutions to adapt, maintain, and recover their educational operations through digital platforms—have gained traction as central frameworks for understanding how universities navigate crises. In essence, digital resilience encompasses not only the technological capacity of an institution to deliver content online, but also the policy structures, faculty readiness, student engagement, and cultural environments that determine the effectiveness and sustainability of these efforts.

While digital resilience has captured the interest of policymakers and researchers globally, its relevance becomes particularly pronounced in conflict-affected and resource-constrained contexts. In regions facing ongoing instability, infrastructural damage, economic volatility, and disrupted governance structures, building and maintaining digital resilience poses significant challenges. Under such circumstances, questions arise about how higher education institutions can continue educating students, safeguarding knowledge production, and preserving academic standards amid limited connectivity, power shortages, and constrained financial resources.

In this regard, Yemen provides a compelling case. The country's protracted conflict and economic hardships have severely impacted its educational sector. Universities confront not only the technical hurdles of unreliable electricity and scarce internet access, but also a broader set of constraints that include governance issues, lack of strategic planning, faculty shortages, and cultural barriers to technology adoption. The advent of the COVID-19 pandemic in this already fragile environment further tested higher education institutions' ability to pivot to digital methods of teaching and learning. Faced with the urgent need to maintain educational continuity, universities were compelled to adopt online or hybrid modalities, offering a unique vantage point to assess how effectively they fostered digital resilience under extraordinary pressure.

This research focuses on the experience of Aden University—one of Yemen's most prominent public universities—as it sought to implement digital learning solutions during the pandemic. By examining the institution's approaches, responses, and the lived experiences of both faculty and students, the study aims to illuminate the complex interplay of infrastructural, sociopolitical, economic, and cultural factors that shape digital resilience. Rather than viewing technology adoption in isolation, this analysis positions the university's digital adaptations within the broader context of Yemen's challenges, highlighting the delicate balance between infrastructure development, faculty capacity-building, policymaking, community trust, and cultural norms.

Through this lens, the following chapters explore the core research questions: What is the current state of digital resilience in Yemeni higher education, specifically in online or remote learning contexts? Which infrastructural, economic, governance, and social barriers impede the adoption of digital learning? And how have Yemeni universities, exemplified by Aden

University, adapted to these challenges, and what outcomes have these adaptations produced? By addressing these questions, the study hopes to provide insights into the conditions necessary for digital resilience to take root in conflict-affected higher education environments and offer evidence-based recommendations for policymakers, educational leaders, and stakeholders invested in strengthening academic continuity amid crisis.

1. Context

Education is a fundamental human right and serves as a cornerstone for social and economic development. In times of crisis, the role of education becomes even more critical, providing a sense of normalcy, supporting healing, and restoring hope for affected populations (Education Cannot Wait [ECW], 2020; Moore & Hodges, 2020). Yemen, a country embroiled in conflict since 2014, faces severe challenges in its education sector, particularly in higher education. The compounded effects of ongoing conflict and the COVID-19 pandemic have disrupted educational systems, leading to significant setbacks in the nation's human capital development.

The protracted conflict has devastated Yemen's educational infrastructure, resulting in over 4.5 million children—39% of the school-age population—being out of school (Save the Children, 2024). The war has led to the partial or complete destruction of approximately 475 schools and 13 universities, with many educational facilities repurposed as shelters for internally displaced persons (IDPs) (Save the Children, 2024). Displaced children are particularly affected, being twice as likely to drop out of school compared to their non-displaced peers, with dropout rates of 58% and 27%, respectively (Save the Children, 2024). While the ongoing conflict has severely disrupted educational infrastructure, the emergence of the COVID-19 pandemic further compounded these challenges. Globally, education has been hit hard by the pandemic, with 1.52 billion learners out of school and 87.1% of the world's total enrolled learners affected by school closures (ECW, 2020). In Yemen, the pandemic intensified pre-existing vulnerabilities, disrupting remaining educational activities and hindering millions of students' access to learning.

Technological infrastructure in Yemen remains underdeveloped, posing significant barriers to the adoption of digital learning solutions. As of 2016, only 1.7% of the population had access to 3G or mobile internet services, primarily because only the state-owned operator, Yemen Mobile, was permitted to provide 3G services (Halewood & Decoster, 2016). Internet speeds are among the slowest globally, with Yemen suffering from an average internet speed of 0.38 Mbps, ranking it 207th in the world (Al-Baadani & Abbas, 2020). Additionally, over 25% of the telecommunications infrastructure has been irreversibly impaired due to the conflict (Halewood & Decoster, 2016). The high cost of telecommunications services further limits accessibility. A data-only mobile broadband package costs about 10% of the monthly Gross National Income (GNI) per capita, significantly above the United Nations' 2% affordability target (Fadhl & Sacchetto, 2023; Halewood & Decoster, 2016). For the bottom 40% of Yemen's population, over 51% of earnings would need to be devoted solely to mobile internet services (Al-Baadani & Abbas, 2020). These economic barriers make digital education unattainable for most students and faculty.

Governance issues compound the infrastructural challenges. Restrictive policies have limited private sector participation in the telecommunications industry; private operators were only permitted to offer 2G services, hindering internet accessibility (Halewood & Decoster, 2016). Political influence and nepotism further undermine institutional efficiency, with appointments often based on affiliations rather than merit (Muthanna & Sang, 2017). The lack of strategic planning and contingency measures in higher education institutions has left them ill-prepared to respond to crises like the COVID-19 pandemic (Al-Baadani & Abbas, 2020).

Economic hardships significantly impact both educators and learners in Yemen. Faculty members face unpaid or drastically reduced salaries, forcing many to seek alternative employment or leave the country in search of better opportunities—a phenomenon contributing to the brain drain (Khaled, 2024; Muthanna, 2015). For students, the cost of education is prohibitive. Families are burdened with school fees averaging at least $50 per student per year, unaffordable for many in a country where the economic situation has deteriorated sharply (Save the Children, 2024). Child labor has become a coping mechanism for families facing financial strain, with approximately 44% of parents and children reporting that the need to support family income was a primary reason behind school dropouts (Save the Children, 2024).

Vulnerable groups, including girls, refugees, and children with disabilities, face heightened barriers to education. Girls are twice as likely to be out of school in crisis situations and are more susceptible to gender-based violence and exploitation when not in school (ECW, 2020). The interruption of education not only affects academic development but also exposes children to increased risks of mental health issues such as stress, anxiety, and depression (Al-Baadani & Abbas, 2020). Educational institutions play a critical role in providing mental health and psychosocial support. Schools and learning centers serve as safe spaces where communities can address health-related issues, including mental well-being (ECW, 2020). The disruption of these services due to conflict and the pandemic has left many students without essential support systems.

Given these multifaceted challenges, Yemen's higher education sector is at a critical juncture, facing barriers that hinder the implementation of effective and resilient digital learning environments. Infrastructural limitations, including severely restricted internet access, slow speeds, and damaged telecommunications infrastructure, make traditional online education models impractical (Fadhl & Sacchetto, 2023; Halewood & Decoster, 2016). The high cost of internet services relative to income levels further exacerbates accessibility issues (Al-Baadani & Abbas, 2020). Governance and policy challenges contribute to the problem, with restrictive regulations limiting the expansion of telecommunications services and private sector participation (Halewood & Decoster, 2016). The absence of strategic planning and effective governance models undermines institutions' capacity to adapt to crises (Al-Baadani & Abbas, 2020). Economic constraints place additional burdens on

educators and students, leading to a loss of qualified professionals through brain drain and compelling students to enter the workforce prematurely (Khaled, 2024; Muthanna, 2015; Save the Children, 2024).

The inability to implement effective digital learning solutions has led to a significant disruption in educational continuity. There is a risk of a "lost generation" of professionals, which would have profound long-term implications for Yemen's development and human capital (Khaled, 2024). Educational inequalities are widening, particularly affecting vulnerable populations such as girls and displaced children (ECW, 2020). The prolonged disruption increases the likelihood of permanent dropouts, exacerbating socioeconomic disparities.

Addressing these challenges requires urgent research to identify viable strategies for building digital resilience in Yemen's higher education sector. There is a notable gap in the literature concerning the general status of digital resilience in online or remote learning within conflict-affected regions with limited infrastructure. Exploring adaptive models like Emergency Remote Teaching (ERT) and low-tech educational solutions could provide pathways to mitigate the current educational crisis.

Purpose of the Study

This study aims to:

- **Objective 1**: Assess the general status of digital resilience in online or remote learning within Yemen's higher education institutions.
    - **Research Question 1**: What is the current state of digital resilience in online or remote learning in Yemen's higher education institutions?
- **Objective 2**: Identify the barriers to implementing effective digital learning environments in Yemen's higher education institutions.
    - **Research Question 2**: What infrastructural, economic, governance, and social barriers do higher education institutions in Yemen face in adopting digital learning?
- **Objective 3**: Analyze the adaptations made by educational institutions in response to these challenges and evaluate their outcomes.
    - **Research Question 3**: How have higher education institutions in Yemen adapted to these barriers, and what are the outcomes of these adaptations?

By addressing these objectives, the research seeks to provide actionable recommendations for policymakers, educational leaders, and international organizations working to enhance educational resilience in Yemen.

2. Methodology

This study employs a **mixed-methods research approach** to explore the challenges and opportunities for building digital resilience in Yemen's higher education system, focusing on Aden University during the COVID-19 pandemic. The approach combines quantitative data from surveys of 40 students with qualitative insights from interviews with key faculty members, administrators, and students. Aden University was chosen due to its status as one of the oldest and most prominent public universities in Yemen. Located in the port city of Aden, the university has been significantly affected by the ongoing conflict and economic instability. Its diverse faculties and student population provide a comprehensive representation of the challenges faced by higher education institutions in Yemen.

The mixed-methods approach is suitable for exploring phenomena within their real-life context, particularly in conflict-affected regions where variables are intertwined and cannot be isolated. The analysis is grounded in an integrated theoretical framework comprising Resilience Theory, the Technology Acceptance Model (TAM), and Diffusion of Innovations (DOI) Theory. This multi-theoretical approach provides a comprehensive lens to examine individual, organizational, and systemic factors influencing digital resilience in Yemen's higher education sector.

(1) Resilience Theory pertains to the capacity of institutions to withstand, adapt to, and recover from adversities or disruptions (Tagarev, 2019). In the context of higher education, it relates to an institution's ability to maintain educational continuity despite challenges such as conflicts, pandemics, or infrastructural deficiencies.

(2) The Technology Acceptance Model (TAM) (Davis, 1989) explains how users come to accept and use technology, emphasizing that perceived usefulness and perceived ease of use influence attitudes toward technology adoption. Understanding these perceptions helps identify barriers to technology adoption, such as lack of digital literacy or cultural resistance, and informs interventions to enhance acceptance.

(3) The Diffusion of Innovations (DOI) Theory (Rogers, 2003) describes how new ideas, practices, or technologies spread within a social system over time. Factors influencing adoption include relative advantage, compatibility, complexity, trialability, and observability.

Integrating these theories enables a multi-level analysis of digital resilience at Aden University. Resilience Theory addresses institutional adaptability, TAM focuses on individual attitudes toward technology, and DOI Theory examines the spread of innovations within the institution. This comprehensive framework guides the thematic analysis of data, allowing for a nuanced understanding of the challenges and opportunities in building digital resilience.

As for the data collection process, data were collected using surveys and semi-structured interviews to capture both quantitative and qualitative insights. An online survey was administered to 40 students from various faculties at Aden University. The survey aimed to assess students' access to technology, internet connectivity, perceptions of the university's response during the pandemic, and changes in academic performance. The questionnaire is included as an annex at the end of this paper.

Furthermore, semi-structured interviews were conducted with students from different faculties[1], alongside interviews with faculty members[2]. These interviews aimed to capture firsthand experiences of students during the pandemic, providing deeper insights into the challenges faced in digital learning environments, as well as providing in-depth perspectives on institutional responses, faculty preparedness, infrastructural challenges, and adaptive strategies employed during the pandemic.

The collected data were analyzed using thematic analysis, guided by the integrated theoretical framework of Resilience Theory, the Technology Acceptance Model (TAM), and Diffusion of Innovations (DOI) Theory. This framework facilitated the identification of key themes related to infrastructural challenges, faculty resistance, cultural and socio-economic factors, and institutional adaptations. The analysis aimed to understand how these factors interact to influence digital resilience in the context of Aden University.

[1] *Medicine, Computer and IT, Languages and Translation, Arts, and Engineering*

[2] *the Vice President for Academic Development, IT Administrator in Aden University, the Dean of the Faculty of Languages and Translation, the Dean and a faculty member from the Faculty of Education.*

3. Findings

The findings of this study highlight the significant barriers to digital learning implementation at Aden University during the COVID-19 pandemic, as well as the institutional adaptations and their impact on student engagement and performance. Data from surveys and interviews with faculty members provide insights into infrastructure challenges, faculty preparedness, cultural and socioeconomic factors, and administrative efforts.

Barriers to Digital Learning Implementation

(1) Governance and Policy Challenges

Governance challenges significantly impact the higher education sector's capacity to adopt digital learning. The Ministry of Higher Education, operating under the Internationally Recognized Government (IRG), took specific steps to support digital learning initiatives during and after the COVID-19 pandemic. The ministry conducted meetings with university administrators across regions under its control to collaboratively address the shift to online and hybrid education, assess the needs of these institutions, and offer assistance when possible. According to the Vice President of Academic Development at Aden University, "the University of Aden spearheaded the establishment of guidelines for hybrid learning for higher education institutions across all freed regions of Yemen." This initiative took place during a meeting with the Ministry of Higher Education and the Higher Council for Learning, headed by former Prime Minister Maeen Abdulmalik Saeed. The University of Aden proposed the guidelines, which were subsequently approved by the council. The Minister of Higher Education then standardized these guidelines across all IRG-controlled regions, ensuring a unified approach to digital education.

Although the study did not identify any further involvement of the ministry beyond its standard duties in direct response to the pandemic, the collaboration between the ministry and universities to assess and address institutional needs demonstrates a coordinated effort to enhance digital resilience in Yemen’s higher education sector. However, much work remains to be done. This study was not able to measure the efforts made by the Ministry of Higher Education under the control of Ansarallah (commonly known as the Houthis) and the Revolutionary Council in the northern parts of Yemen. Instead, it incorporated studies published by universities under the control of the Revolutionary Council to provide a comprehensive overview of the governance and policy landscape affecting digital transformation.

Despite the governance-level efforts done by Aden University's administration – later discussed in the Mitigation Measures to Challenges of Digital Learning section of this paper –, significant issues exist within the broader governance structures across Yemen's higher education sector.

Muthanna (2015) identifies nepotism, lack of meritocracy, and corruption as significant impediments to educational quality in Yemen. University leaders are often appointed based on political affiliations rather than expertise, leading to ineffective governance (Al-Haimi, 2016). These governance issues hinder the implementation of supportive policies necessary for digital transformation.

Regulatory policies play a crucial role in technology adoption. However, Yemen's policies are often unsupportive or insufficiently developed to facilitate digital transformation (Alghushami et al., 2020). The Ministry of Finance's control over universities limits their autonomy and stifles innovation (Al-Haimi, 2016). Institutional theories suggest that governance structures influence an organization's ability to adapt and implement reforms (Scott, 2014). The lack of strategic planning and contingency measures leaves higher education institutions ill-prepared to respond to crises like the COVID-19 pandemic (Al-Baadani & Abbas, 2020). The Dean of the Faculty of Education noted that the COVID-19 response in Yemen's higher education sector must be studied and evaluated to develop future emergency responses.

(2) Infrastructure Challenges: access to electricity, internet and devices

Digital infrastructure is foundational to remote learning, comprising elements such as high-speed broadband, reliable hardware, and learning management systems that enable effective educational delivery. The COVID-19 pandemic highlighted the critical role of digital infrastructure as schools with limited digital capacity faced challenges that widened educational inequalities and learning losses (Timotheou et al., 2023). These issues underscore the importance of enhancing digital capacity to ensure the continuity and quality of education during emergencies. Interviews revealed that frequent power outages severely hindered digital learning efforts at Aden University. A faculty member from the Faculty of Education mentioned that "the electricity was off for 20 hours since yesterday," illustrating the extent of the issue. This aligns with Fadhl and Sacchetto's (2023) observation that the ongoing conflict has severely damaged Yemen's telecommunications infrastructure, leading to an unreliable electricity supply. The Digital Divide Theory (Norris, 2001), which addresses the gap between those who have access to information and communication technologies (ICT) and those who do not, is clearly exemplified in this context.

Building on these infrastructural insights, survey results further emphasize the depth of connectivity challenges: only 15.2% of students reported reliable internet access for more than six hours a day, while 36.4% indicated having just one to three hours of reliable access.

Students' perception of "reliable internet" is significantly lower than global standards. According to AlTameemy and Alrefaee (2021), Yemen ranks 207th globally in internet speed, a factor that directly impacts students' capacity to engage in digital learning. Additionally, an interview with the Vice President for Academic Development revealed that a $6 million Chinese grant intended for infrastructure improvements has not yet been operationalized, further exacerbating connectivity issues. While the Faculty of Languages and Translation had been utilizing hybrid teaching methods since 2014, giving them an advantage during the COVID-19 pandemic, their experience also underscores a broader challenge: the lack of similar proactive investments across other faculties. The Dean noted that their prior experience with blended learning enabled a smoother transition compared to other faculties, highlighting the uneven distribution of digital readiness within the university. This disparity reflects the systemic underinvestment in digital competencies, leaving most faculties ill-prepared to handle the demands of remote learning.

These infrastructural challenges, including power outages, limited internet access, and inadequate devices, reflect the severe underdevelopment of Yemen's ICT sector, impeded by regulatory barriers and limited infrastructure (Halewood & Decoster, 2016). The prolonged conflict and underinvestment have widened the digital divide in Yemen, hindering digital transformation efforts in higher education (World Bank, 2017).

Students reported severe internet connectivity issues and unreliable electricity, aligning with survey findings. A student from the Faculty of Computer and IT, stated, *"The situation was really bad... we needed better support, both in terms of planning and technology."* Malware-infected USB drives further hindered access to educational materials, with her noting that some students' laptops were damaged due to infections. Some students relied on cybercafés or campus labs, but frequent power outages, high usage costs, and safety concerns often disrupted their access to these facilities. Many also depended on smartphones, which were impractical for tasks like typing essays or navigating multiple platforms due to their limited functionality. Shared laptops within households further compounded the issue, as students often had restricted access, leading to interruptions in their study sessions.

(3) Faculty Resistance and Technical skills gap

The Vice President's remark highlights that faculty intended to employ multiple digital teaching strategies. These included using video conferencing tools like Zoom for live lectures, uploading recorded tutorials and narrated presentations to cloud storage (e.g., Google Drive), and assigning and collecting homework through online platforms. Some planned to incorporate interactive quizzes hosted on simple e-learning tools and provide individualized feedback using shared folders or basic Learning Management Systems. Essentially, they aimed to move beyond static email exchanges and create a more interactive, multi-modal online learning environment.

Yemeni educators often lack digital literacy and confidence in using e-learning platforms (Aljohani & Agarwal, 2022). Pongsakdi et al. (2021) found that such training enhances teachers' ICT confidence, particularly among those initially lacking self-assurance. Essentially, "targeted digital pedagogy training" refers to focused, practical sessions that address the specific needs and skill gaps of educators. Rather than generic lectures on technology use, these sessions might include step-by-step guidance on setting up online quizzes, creating short video demonstrations for complex topics, or using screen-sharing tools to walk students through problem-solving exercises. For example, consider a math teacher learning to record brief tutorial clips showing step-by-step solutions to equations, then uploading these clips to a learning platform. Students can watch the tutorials at their own pace and submit follow-up questions online. This approach transforms a previously static, textbook-based lesson into a dynamic, interactive experience that fosters deeper engagement and understanding.

The phenomenon of educator migration (brain drain) contributes to a reduction in the number of experienced faculty members available to support digital initiatives. Some skilled teachers seek opportunities abroad (Muthanna, 2015), influenced by factors such as limited professional growth prospects or financial constraints. As these educators depart, the local higher education environment is left with fewer long-term professionals to guide the implementation of new technologies, potentially slowing the progress toward enhanced digital resilience.

Another student from the Faculty of Medicine expressed frustration over inconsistent and low-quality online lectures. He mentioned, *"The lectures were just short clips... nowhere near enough to understand the material."* such material was shared over popular messaging apps like WhatsApp or file sharing and management platforms like Google Drive. Methods differed between each professor making the process even more confusing for the students.

Educational materials, including recorded lectures and reading resources, were primarily created by faculty members without any prior training or institutional support in production. A student from the Faculty of Computer & IT highlighted the issues with recorded lectures, noting poor audio quality and lack of engagement, stating, "Sometimes you would hear a kid crying in the background, or the professor's voice would suddenly cut off." Faculty members, often inexperienced with recording equipment and software, struggled to produce clear and engaging content. Without standardized guidelines or a unified platform, videos were shared through inconsistent methods such as WhatsApp, USB drives, or basic cloud links, adding to students' difficulties in accessing and navigating learning materials.

Findings suggest that older faculty members were more resistant to adopting new teaching methods. The Vice President noted, "Faculties teaching applied sciences believed hands-on learning couldn't be replaced," reflecting skepticism about the efficacy of digital learning in certain disciplines. This resistance aligns with Alghushami et al. (2020), who found that

cultural factors, such as tribalism, negatively impact trust and acceptance of new technologies within higher education institutions.

The **Technology Acceptance Model (TAM)** (Davis, 1989) posits that perceived usefulness and ease of use influence technology adoption. The lack of digital literacy and resistance to change among faculty members reduce the perceived ease of use, hindering adoption. Addressing these attitudes through training and demonstrating the effectiveness of digital methods is crucial for successful implementation.

Faculty resistance and the technical skills gap impact technology adoption. According to TAM, perceived usefulness and ease of use influence users' acceptance of technology (Davis, 1989). The lack of digital literacy among educators and skepticism about digital learning's efficacy hinder perceived ease of use and usefulness, leading to resistance. Addressing these factors through targeted training and support can enhance technology acceptance (Pongsakdi et al., 2021; Aljohani & Agarwal, 2022).

(4) Cultural and Socioeconomic Factors

Survey data showed that only 29.4% of students have laptops, limiting their ability to fully engage in digital learning. The Dean of the Faculty of Languages and Translation mentioned that some faculty members provided laptops to students who couldn't afford them, demonstrating efforts to mitigate economic barriers. However, this supply is severely limited and cannot cover the student population in need of access to such technology.

Economic hardships significantly impact access to technology. High data costs and device affordability issues limit access to digital learning (Al-Baadani & Abbas, 2020). The high cost of telecommunications services—about 10% of the monthly Gross National Income per capita—makes digital education unattainable for most students and faculty (Fadhl & Sacchetto, 2023). These economic barriers widen the digital divide (Norris, 2001), as many cannot afford the necessary tools for online education. Interviews and survey responses suggest that students without personal laptops resorted to a range of suboptimal alternatives. Some relied on smartphones to access course materials, but small screens, limited typing capabilities, and slow loading times for large files hindered their ability to engage effectively with online content. The cost of mobile data and Yemen’s sluggish internet speeds compounded these difficulties, making regular attendance in online sessions challenging. In households where multiple siblings were enrolled in remote classes, sharing a single device became common, often forcing students to compete for screen time and access course materials during off-peak hours. While some considered using university computer labs or visiting local cybercafés, these options were limited by restricted operating hours, additional expenses, and occasional closures, particularly for students living far from campus. For the faculty and staff, the interviews did not indicate a systematic provision of university-owned laptops or tablets for instructors. Although the Dean of the Faculty of

Languages and Translation noted attempts to lend laptops to a limited number of students, similar efforts for faculty were not clearly reported. Many instructors relied on personal devices under the same infrastructural and connectivity constraints as their students. Without reliable, institution-provided hardware or comprehensive technological support, faculty members struggled to produce, upload, or manage digital learning materials consistently, further affecting the quality and accessibility of online education.

Cultural factors, including tribalism and traditional educational norms, contributed to resistance against adopting digital technologies. Alghushami et al. (2020) emphasized that tribalism negatively impacts trust and acceptance of new technologies within institutions, posing a barrier to digital learning implementation. Gender disparities further complicate access to education, with girls' enrollment rates significantly lower due to cultural factors and economic constraints.[3]

The **Diffusion of Innovations Theory** (Rogers, 2003) explains that innovations spread within a social system based on factors like compatibility with existing values and practices. In Yemen, cultural resistance affects trust and acceptance of new technologies, hindering their diffusion within educational institutions.[4] Addressing these cultural barriers requires policies that promote inclusivity and community engagement to build digital trust.

Mitigation Measures to Challenges of Digital Learning

Challenges impacted students' learning resources and academic performance. Due to inadequate support, students resorted to self-study. A student from the Faculty of Medicine noted that he relied on YouTube to fill educational gaps, stating, "most of my learning happened on YouTube." Students from the Faculty of Computer & IT avoided using infected USBs and turned to old notes and online resources for learning.

From another perspective, the Dean of the Faculty of Languages and Translation observed, "Student performance dropped during the pandemic." The faculty member added, "Students from remote areas struggled the most," highlighting disparities based on geographic location and access to resources.

47.1% of survey respondents reported no observable change in their grades during the pandemic, while 32.4% indicated their grades dropped, and 20.6% reported an improvement. These results suggest varied impacts on academic performance. These results also justify students' evaluation of the university's approach on online learning. A significant proportion of students rated the university's approach during lockdown poorly. Specifically, 47.1% gave it the lowest possible score (1 out of 5), and 91.2% rated it 3 or below. No respondents rated the university's efforts as a 5.

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[3] *Achieving Education for All in Yemen: Assessing the Current Challenges and Progress* (2018), [Report].
[4] *Rogers, E. M. (2003). Diffusion of innovations (5th ed.). Free Press.*

These findings underscore the exacerbation of existing inequalities due to the pandemic. Students from disadvantaged backgrounds faced greater challenges, aligning with the literature that the COVID-19 pandemic exposed and intensified educational disparities (ECW, 2020). The lack of comprehensive crisis management strategies in Yemeni universities led to significant obstacles in maintaining educational continuity (Alshowaiter, 2021).

On the other hand, a few mitigating measures were highlighted in the survey and interviews on the level of policies, digital infrastructure and lecturers' digital knowledge.

(1) Early adaptation of hybrid education

Early adaptation of hybrid education at Aden University involved a layered response from multiple stakeholders—government authorities, the university administration, faculty members, and students—each attempting to mitigate previously identified challenges, including infrastructural deficits, governance issues, limited faculty preparedness, and cultural barriers.

The Faculty of Languages and Translation, having experimented with blended learning before the pandemic, could quickly adapt to official policies by leveraging their prior experience in online content creation, lecture recording, and partial virtual instruction. Their success, in line with the Diffusion of Innovations (DOI) Theory (Rogers, 2003), served as a model, demonstrating to other faculties the relative advantage and compatibility of integrating technology into pedagogy. Meanwhile, other faculties attempted diverse solutions: some tried organizing basic technical training sessions for teachers, others encouraged informal peer mentoring where more tech-savvy lecturers guided colleagues in recording tutorials or managing virtual sessions. While no large-scale, well-funded faculty training program emerged, these piecemeal efforts indicate attempts to address the skills gap highlighted by the Technology Acceptance Model (TAM) (Davis, 1989). In essence, educators recognized that even minimal technical upskilling—learning to share Zoom links, upload lecture recordings, or use simple online quiz tools—could make a difference in student learning outcomes.

Students, for their part, actively engaged with these mitigation measures where possible. Confronted with weak infrastructure and inconsistent faculty preparedness, many students took advantage of the new policies allowing flexible modalities. Some joined online sessions when available, others downloaded or shared recorded materials among peers, making ad hoc study groups to fill gaps left by infrastructural and faculty limitations. When policies allowed more lenient attendance and assessment, students could focus on self-study or rely on alternative learning materials, such as YouTube tutorials or international MOOCs. Although these student-driven adaptations highlight resilience, they also underscore the uneven quality of support; without stable internet or consistent faculty input, students bore much of the burden of adapting.

In practice, while each stakeholder group implemented certain mitigation strategies, the effectiveness of these measures remained constrained. Government-level policies provided a conceptual framework for hybrid learning but offered limited technical support or funding. The university's committee formulated guidelines but could not overcome deep-rooted infrastructural and financial constraints. Faculty members, even with minor capacity-building efforts, struggled to uniformly improve digital literacy and engagement, and students, despite utilizing flexible attendance and leaning on informal peer networks, continued to face connectivity and equipment hurdles. As a result, while these early attempts at hybrid education and related interventions represent meaningful efforts to implement the recommendations emanating from the government's and the university's policy environment, they ultimately revealed that policy directives, training endeavors, and infrastructural upgrades must be more robust, coordinated, and culturally attuned to sustain genuine digital resilience in Yemen's higher education landscape.

(2) Use of Local Wi-Fi Networks

The findings highlight the importance of adaptive capacity in educational institutions facing crises. Aden University's infrastructural challenges and limited resources constrain its ability to absorb shocks and reorganize while maintaining essential functions (Tagarev, 2019). The innovative strategies employed by faculties demonstrate resilience but also reveal the need for systemic support to enhance institutional resilience. Building resilience requires not only innovative adaptations but also addressing underlying infrastructural and governance issues.

To overcome connectivity challenges, a faculty member from the Faculty of Education employed innovative methods by storing lectures on local Wi-Fi networks. This approach allowed students to download materials without relying on unstable internet connections. This strategy aligns with Tuparov et al.'s (2019) suggestion that mobile internet access is more feasible than fixed-line connections due to infrastructure destruction, making mobile learning a practical solution.

To eliminate the challenges of limited digital infrastructure, alternative content distribution methods were used, for example:

- **USB-Based Lecture Distribution:** The Faculty of Computer and IT distributed lectures and study materials through USB drives. Students would receive these USBs and share the materials among their peers, minimizing internet dependency and reducing exposure risk associated with gatherings.
- **WhatsApp Groups for Lecture Sharing:** Several faculties recorded lectures and shared them via WhatsApp groups, leveraging the widespread use of mobile devices and the accessibility of WhatsApp. Despite its unstructured nature, this method proved effective in reaching students who faced internet connectivity issues or lacked access to more formal platforms.

These adaptations reflect the need for flexible and low-tech solutions in contexts with limited infrastructure. Koole's FRAME model (2009) conceptualizes mobile learning as the intersection of device usability, learner characteristics, and social interaction. By utilizing familiar platforms and accessible devices, faculties enhanced the practicality of mobile learning.

(3) Conducting trainings or seeking assistance

Addressing faculty's lack of digital competencies proved challenging in the absence of formal, large-scale training programs organized by Aden University or the Ministry of Higher Education. While official directives encouraged a shift to online or hybrid modalities, no comprehensive, institution-wide initiative was launched to equip lecturers with the necessary technical and pedagogical skills. Lecturers were largely left to navigate new technologies—such as recording software, learning management systems, and communication platforms—without systematic guidance or instructional design support. Similarly, students emphasized the need for technological improvements and faculty training. One suggested that the university should provide greater access to technology and invest in training faculty, stating, "The entire system needs to transition to modern technologies...both students and faculty need training." Others recommended better planning and safe methods for content distribution to avoid issues like malware, security, and accessibility.

4. Discussion

This study aimed to explore the challenges and opportunities for building digital resilience in Yemen's higher education system, focusing on Aden University during the COVID-19 pandemic. By analyzing the findings through the lenses of Resilience Theory, the Technology Acceptance Model (TAM), and Diffusion of Innovations (DOI) Theory, we gain a comprehensive understanding of the factors influencing digital learning implementation and the institutional adaptations that occurred.

4.1 Interpretation of Findings

Infrastructure as a Fundamental Barrier

Unreliable electricity and poor internet connectivity emerged as significant barriers. Only **15.2%** of surveyed students had reliable internet access for more than six hours daily, and frequent power outages were reported—one faculty member stated that **"electricity was off for 20 hours since yesterday."** These issues hindered students' engagement with online platforms and limited faculty's ability to deliver digital content.

The students' experiences corroborate the infrastructural challenges identified. The issue of malware-infected USBs, as highlighted by interviewed students, adds a layer of complexity to the digital divide (Norris, 2001), demonstrating how inadequate solutions can exacerbate existing problems.

Resilience Theory emphasizes the importance of adaptive capacity in facing adversities (Tagarev, 2019). Aden University's infrastructural challenges highlight limitations in this capacity. External factors like national infrastructure deficits and delays in projects, such as the nonfunctional **$6 million Chinese grant**, compromise the university's ability to absorb shocks and continue functioning, underscoring the need for resilience planning.

Faculty Resistance and Adoption

A gap in technical skills among faculty and resistance to new teaching methods, especially among older educators, were evident. The Vice President noted, **"Many faculty members lacked the necessary skills for hybrid teaching,"** and **"faculties teaching applied sciences believed hands-on learning couldn't be replaced."** Student's accounts of poor-quality online lectures and lack of faculty engagement illustrate the impact of faculty preparedness on student learning.

According to TAM (Davis, 1989), perceived usefulness and ease of use significantly influence technology acceptance. Faculty doubting digital learning's effectiveness or finding technologies challenging were less likely to adopt them. This aligns with Aljohani and

Agarwal's (2022) assertion that digital literacy enhances educators' adaptability. Enhancing digital literacy and providing support can positively influence attitudes toward technology adoption, supporting TAM's premise and Pongsakdi et al.'s (2021) recommendation for targeted training.

Innovative Adaptations

Despite constraints, successful adaptations occurred. A faculty member stored lectures on local Wi-Fi networks, allowing student access without relying on unstable internet connections: **"I stored my lectures on local networks for students to access."** The Faculty of Languages and Translation's early adoption of hybrid methods since 2014 positioned them as early adopters better prepared during the pandemic.

While some faculties attempted solutions like local Wi-Fi networks, the students' experiences suggest these efforts were insufficient or poorly implemented. A student from the faculty of Computer & IT mentioned an unsuccessful attempt to create a local network, which *"was complicated, slow, and eventually discontinued."* This indicates a need for better-planned and supported innovations.

DOI Theory (Rogers, 2003) explains how innovations spread within a social system. The Faculty of Languages and Translation exemplifies early adopters influencing others through communication channels and social networks. Their success demonstrates the potential for hybrid learning models to diffuse throughout the university if supported by effective communication and observable benefits.

4.2 Recommendations

The COVID-19 pandemic served as a stress test for Aden University's operational capabilities, revealing both strengths and weaknesses in its approach to crisis management and digital learning implementation. Recognizing and analyzing these experiences is crucial for developing robust plans for future emergencies. By leveraging the lessons learned and involving all stakeholders—government, international organizations, university administration, faculty, students, and the community—the university can foster a collaborative effort to enhance resilience and adaptability.

Policy and Governance Reforms

- **Encourage Government Support for Digital Education Policies:** Advocate for policies that support digital transformation in higher education, including funding allocations and regulatory frameworks that promote autonomy and innovation. Through engaging in dialogue with policymakers to highlight the importance of digital

education, participating in national education forums and contributing to policy drafts, and collaborating with other universities to strengthen advocacy efforts.

- **Collective Responsibility Among Stakeholders:** Foster collaboration between the university administration, faculty, students, government bodies, international organizations, and the private sector to address challenges collectively, as suggested by Alghushami et al. (2020). Through establishing stakeholder committees to facilitate communication and joint planning, organizing forums and workshops that include all parties to discuss challenges and solutions and developing partnerships with private companies for technological support and sponsorships.

- **Conduct Retrospective Analyses:** The university should systematically review the strategies implemented during the pandemic to identify what worked and what did not. This reflective practice enables the institution to learn from successes and mistakes, fostering continuous improvement and innovation, and could be implemented by establishing a task force to document and evaluate the pandemic response, collecting feedback from faculty, students, and staff through surveys and focus groups and developing a report outlining key findings and recommendations for future crises.

- **Develop Emergency Response Plans:** Building on the lessons learned, the university can formulate comprehensive emergency response plans that are adaptable to various crises, not limited to health emergencies. Such plans would enhance the institution's resilience and ability to maintain educational continuity under adverse conditions. Universities can create a crisis management committee responsible for developing and updating emergency plans, include protocols for various scenarios, such as natural disasters or political instability, and regularly train faculty and staff on emergency procedures.

- **Efficient Resource Allocation:** Given the university's shrinking financial resources, it is imperative to prioritize investments in areas that enable the institution to thrive. By eliminating inefficiencies and focusing on high-impact initiatives, the university can maximize the return on its limited funds. Universities should conduct a financial audit to identify areas of unnecessary expenditure, prioritize funding for critical infrastructure and capacity-building programs and explore alternative funding sources, such as grants and partnerships.

- **Regularly Evaluate and Adjust Strategies:** Implement a continuous feedback loop where strategies are regularly assessed for effectiveness, and adjustments are made promptly. This agile approach allows the university to respond quickly to changing circumstances and optimize resource utilization. This could be implemented through setting up Key Performance Indicators (KPIs) to measure progress, holding quarterly

reviews to assess strategy implementation and adjusting plans based on data-driven insights and stakeholder feedback.

Infrastructure Development

- **Advocate for Completing Infrastructure Projects:** Prioritize the activation of delayed projects like the Chinese grant to improve electricity and internet connectivity, which are foundational for digital learning by engaging with government officials to expedite infrastructure projects, providing evidence of the critical need for infrastructure improvements and collaborating with other institutions to present a unified appeal.
- **Conduct International Partnerships:** Seek collaborations with international organizations to secure funding and technical support for infrastructural enhancements, aligning with recommendations from AlTameemy and Alrefaee (2021) on leveraging global support. by identifying potential international partners and donors, preparing proposals outlining the university's needs and potential impact and establishing communication channels with embassies and international agencies.

Capacity Building

- **Implement Ongoing Faculty Training Programs:** Develop comprehensive training initiatives to enhance digital literacy among educators, addressing the technical skills gap and improving perceived ease of use by organizing workshops and seminars on digital tools and pedagogical methods, providing access to online courses and certifications, and establishing a mentorship program pairing tech-savvy faculty with those needing assistance.
- **Provide Technical and Financial Assistance**: Offer expertise, funding, and resources to support digital initiatives and infrastructure development.
- **Support Capacity Building Initiatives**: Assist in developing training programs for faculty and staff to enhance their digital literacy.
- **Engage in Professional Development**: Participate in training to improve digital literacy and adapt to new teaching methods.
- **Adopt Student-Centered Approaches**: Focus on inclusive education by considering the needs of all students, especially those facing technological barriers.
- **Actively Participate in the Learning Process**: Adapt to new learning environments and provide feedback to improve educational delivery.

Innovative Solutions

Expand Use of Mobile Learning Platforms

Leverage the widespread use of smartphones by developing mobile-friendly content and applications, considering the feasibility highlighted by Tuparov et al. (2019).

- **Actionable Steps**:
  - Invest in the development of a university mobile app for learning management.
  - Optimize websites and online resources for mobile access.
  - Utilize SMS and messaging apps for communication and content distribution.

Develop Low-Bandwidth Content

Create educational materials that require minimal data to accommodate students with limited internet access, addressing connectivity challenges.

- **Actionable Steps**:
  - Use text-based resources and compressed files where possible.
  - Provide downloadable content that students can access offline.
  - Avoid heavy reliance on high-resolution multimedia that consumes significant data.

5. Conclusion

This study explored the challenges and opportunities for building digital resilience in Yemen's higher education system, focusing on Aden University during the COVID-19 pandemic. The research identified several significant barriers to the effective implementation of digital learning:

- **Infrastructure Challenges:** Unreliable electricity and poor internet connectivity emerged as fundamental obstacles. Only 15.2% of surveyed students had reliable internet access for more than six hours a day, and frequent power outages severely hindered both students and faculty. These infrastructural issues limited access to online resources and disrupted the continuity of education.
- **Faculty Resistance and Preparedness:** A gap in technical skills among faculty members and resistance to adopting new teaching methods, especially among older educators, limited the transition to digital learning. Many faculty lacked the necessary skills for hybrid teaching, and skepticism existed about the efficacy of online methods for certain disciplines, particularly applied sciences.
- **Cultural and Socioeconomic Factors:** Economic barriers, such as the inability of students to afford laptops and internet access, further impeded digital learning. Cultural resistance, including traditional educational norms, affected the acceptance and adoption of new technologies within the institution.

Despite these challenges, the study also highlighted adaptive strategies and their outcomes:

- **Innovative Teaching Methods:** Faculty members employed creative solutions to overcome infrastructural limitations. For example, lectures were stored on local Wi-Fi networks for students to access without relying on unstable internet connections. The Faculty of Languages and Translation, having adopted hybrid methods since 2014, demonstrated higher readiness and served as a model for effective digital learning implementation.
- **Varying Effectiveness of Adaptations:** The effectiveness of these innovative methods varied across faculties. While some students reported no significant change in academic performance, others experienced declines. Survey results indicated that a majority of students were dissatisfied with the university's approach during the lockdown, highlighting the need for more consistent and effective strategies.

This research contributes valuable insights into the complexities of building digital resilience in a conflict-affected context. By applying Resilience Theory, the Technology Acceptance

Model, and Diffusion of Innovations Theory, the study provides a nuanced understanding of the multifaceted challenges faced by higher education institutions in Yemen.

- **Contribution to Understanding Digital Resilience**: The study underscores the critical role of infrastructure, faculty preparedness, and cultural factors in shaping an institution's ability to adapt to crises. It highlights how external adversities, such as conflict and pandemics, intersect with internal capacities, affecting educational continuity and quality. The findings demonstrate that resilience is not solely dependent on resources but also on the adaptability and collaborative efforts of stakeholders.
- **Implications for Stakeholders**: The research highlights areas requiring attention for policy and practice. For policymakers and government entities, there is a pressing need to invest in infrastructure development and create supportive policies for digital education. Educational institutions must focus on capacity building through faculty training and adopting lean operational models to maximize resource efficiency. International organizations and the private sector can contribute by providing technical and financial assistance, fostering international partnerships, and supporting capacity-building initiatives. Recognizing the interconnected responsibilities of all stakeholders is essential for developing sustainable strategies that enhance digital resilience.

In conclusion, while significant barriers hinder the implementation of digital learning at Aden University, the adaptive strategies observed during the COVID-19 pandemic reveal opportunities for growth and improvement. By leveraging lessons learned and fostering collaboration among stakeholders, there is potential to build a more resilient and adaptable higher education system in Yemen. This study serves as a foundation for future research and practical interventions aimed at overcoming challenges and enhancing the digital resilience of educational institutions in conflict-affected regions.

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