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ORIGINAL RESEARCH ARTICLE

Rethinking Educational Continuity: Digital Inequality and the Shift from System Resilience to Individual Adaptation in Beirut

إعادة النظر في الاستمرارية التعليمية: اللامساواة الرقمية والتحول من مرونة النظام إلى التكيّف الفردي في بيروت

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GRAPHICAL ABSTRACT

INPUT	PROCESS	OUTCOME
Infrastructure instability Digital inequality Limited support	Adaptation strategies Digital skills Resource management	Educational continuity Digital skills strongest factor Sustained participation Uneven learning quality

HIGHLIGHTS

HS1	Digital inequality disrupts educational continuity in Beirut.
HS2	Infrastructure instability limits effective online learning.
HS3	Students rely on adaptation to sustain learning.
HS4	Digital skills strongly influence learning continuity.

HS5	Educational resilience depends on system support.

Figure 1. *The figure presents the study's conceptual Input–Process–Outcome model, illustrating how adaptive practices and digital skills supported educational continuity under conditions of infrastructure instability.*

ABSTRACT

Digital inequality has become an increasingly important challenge for educational continuity in cities experiencing prolonged economic and infrastructural instability. In Beirut, where electricity outages and internet disruptions have become part of everyday life, students' ability to participate in online and hybrid learning depends not only on access to technology but also on their capacity to adapt to unstable learning conditions. Although previous studies have examined digital inequality and educational resilience, limited attention has been given to how these factors interact in crisis-affected urban environments where instability is ongoing rather than temporary. This study investigates how internet reliability, device suitability, and digital skills influence educational continuity among students in Greater Beirut. Guided by a mixed-methods case study design, the research combined survey data from 197 secondary school and university students with interviews and focus group discussions involving students, teachers, and administrators. Quantitative data were analyzed using correlation and multiple regression analyses, while qualitative data were examined thematically to explore participants' experiences of learning under unstable conditions. The findings show that educational continuity remains possible despite persistent infrastructural challenges, but often at a significant cost to learning quality. Internet reliability ($\beta = .18$, $p = .041$), device suitability ($\beta = .24$, $p = .008$), and digital skills ($\beta = .31$, $p = .001$) all significantly predicted educational continuity, with digital skills emerging as the strongest predictor. The regression model explained 34% of the variance in educational continuity ($R^2 = .34$, $F(5,144) = 14.82$, $p < .001$) and produced a large practical effect size (Cohen's $f^2 = .52$). Qualitative findings revealed that students frequently adjusted study schedules, shared connectivity resources, relied on mobile data, and downloaded learning materials in advance to cope with recurring disruptions. However, participants consistently distinguished between maintaining participation and achieving meaningful learning, suggesting that continuity and learning quality do not necessarily develop together under unstable conditions. Drawing on these findings, the study proposes the Adaptive Educational Continuity under Infrastructure Instability framework. The framework explains educational continuity as the product of interactions among infrastructure conditions, digital access, digital skills, and student adaptation. By shifting attention from system reliability to adaptive capacity, the study extends current discussions of digital inequality, educational resilience, and crisis-responsive education, while offering insights

for policymakers and educational institutions operating in similarly unstable environments.

Keywords: digital inequality; educational continuity; infrastructure instability; digital skills; educational resilience; student adaptation; urban resilience; Beirut

1. Introduction

1.1 Background of the Study

Beirut has experienced a sustained period of economic contraction, political instability, and infrastructural deterioration since 2019, a combination of pressures that has left electricity supply and internet connectivity unreliable across much of the city. Schools and universities, like other institutions, have had to adapt their operations to these conditions, and online and hybrid learning arrangements that were initially adopted as emergency measures during the COVID-19 pandemic have in many cases persisted as a structural feature of how education is delivered. This shift means that students' ability to learn now depends, to an unusually large degree, on resources that are themselves unstable: the devices they have access to, the quality of their internet connection, and the electricity needed to keep both running.

This context sets Beirut apart from many of the settings typically studied in the digital divide and online learning literature. Much of that literature was developed with reference to environments where infrastructure, even if unequally distributed, is at least dependable once access is secured. In Beirut, dependability itself cannot be assumed: a student with a suitable laptop and a paid internet subscription may still lose access for hours at a time because of a power cut, independent of household income or digital literacy. Understanding educational continuity in this setting therefore requires looking not only at who has access to digital resources, but at how students manage to keep learning when that access is itself unreliable.

1.2 Problem Statement

Digital technologies have become essential for maintaining educational continuity, especially during periods of disruption. In recent years, crises such as the COVID-19 pandemic and ongoing economic and infrastructural instability have forced schools and universities to rely heavily on online and hybrid learning. As a result, access to stable internet connections, suitable digital devices, and basic digital skills is no longer optional but necessary for students to continue learning.

However, access to these resources remains uneven. In cities experiencing ongoing crises, such as Beirut, many students face unstable internet, frequent electricity cuts, and limited access to appropriate devices. These challenges make it difficult to participate consistently in online learning, complete academic tasks, and maintain progress. When learning conditions become unpredictable, the impact goes beyond academic performance to affect student motivation, engagement, and long-term educational outcomes. If these issues are not addressed, they risk widening existing inequalities and weakening the ability of education systems to function during crises.

1.3 Research Gap

Although there is a growing body of research on digital learning and urban resilience, these areas are often studied separately. Studies on digital education tend to focus on access, technology use, or learning outcomes without considering the broader context in which learning takes place (Selwyn, 2021; Van Deursen & Van Dijk, 2019). At the same time, research on urban resilience focuses mainly on infrastructure, governance, and emergency response, with limited attention to the continuity of education as a core system (Meerow et al., 2016).

More recent studies highlight the importance of digital access in shaping students' learning experiences (Zhao et al., 2024; UNESCO, 2021). However, these studies are often based on relatively stable environments and do not fully capture how digital learning operates in contexts where instability is ongoing. As a result, there is limited understanding of how digital inequality, infrastructure challenges, and institutional conditions interact to affect educational continuity in crisis-affected urban settings.

This study also introduces a conceptual model called Adaptive Educational Continuity under Infrastructure Instability. It shows that in unstable conditions, learning continues not because systems are reliable, but because students find ways to adjust and keep going.

1.4 Research Questions / Hypotheses

Research Questions

RQ1: How do differences in internet reliability, device access, and digital skills affect students' ability to continue learning during disruption in Beirut?
RQ2: What coping strategies do students use to maintain learning continuity under unstable conditions?
RQ3: Which factors most strongly predict educational continuity in this context?

Hypotheses

H1: Internet reliability has a positive and significant effect on educational continuity.

H2: Device suitability has a positive and significant effect on educational continuity.
H3: Digital skills have a positive and significant effect on educational continuity.

1.5 Significance of the Study

This study is important because it addresses a real and ongoing challenge faced by students in crisis-affected environments. By focusing on Beirut, it provides insight into how education systems function under conditions of instability and limited resources. The findings are relevant for teachers, as they highlight the challenges students face in maintaining engagement and performance. They are also important for policymakers and educational institutions, as they emphasize the need for reliable infrastructure, effective digital support, and equitable access to learning tools.

More broadly, the study contributes to understanding how education fits within urban resilience. It shows that maintaining learning continuity is not only an educational issue but also a key part of social stability. By examining digital inequality within this broader framework, the study offers a more integrated perspective on how education systems can be strengthened to respond to future disruptions.

2. Literature Review

2.1 Theoretical Framework

This study is grounded in the integration of three complementary perspectives: urban resilience, digital divide theory, and education system resilience. These frameworks are not treated as separate strands, but as interconnected lenses that help explain how educational continuity is maintained under conditions of disruption.

Urban resilience is commonly understood as the ability of cities to maintain essential functions during periods of stress (Meerow et al., 2016). While earlier work focused mainly on infrastructure and emergency response, more recent approaches recognize that cities operate as interconnected systems that include social, economic, and institutional dimensions. Within this perspective, education should be considered a central component of resilience, as interruptions to learning have long-term consequences for social stability, economic mobility, and community cohesion. However, despite this importance, education remains underrepresented in resilience frameworks.

Digital divide theory explains why access to online learning is experienced unevenly. Earlier research focused primarily on whether individuals had access to devices or internet connections. More recent studies show that inequality also exists in the quality of access, the suitability of devices, and levels of digital skills (Van Deursen & Van Dijk, 2019). Selwyn (2021) further emphasizes that access alone does not guarantee meaningful participation, as students' learning experiences are shaped by their

environment, available support, and study conditions. These issues become more pronounced in crisis contexts, where infrastructure instability limits both access and usability.

Education system resilience focuses on how educational institutions sustain teaching and learning during periods of disruption and adapt to changing conditions in order to maintain continuity. Research shows that institutions with established digital infrastructure and trained staff are better able to maintain continuity, while those with limited preparation experience greater disruption (Liu et al., 2021; Czerniewicz et al., 2020; Motz et al., 2023). However, much of this research assumes relatively stable environments, which limits its applicability in contexts where instability is ongoing.

Recent research has increasingly emphasized that educational resilience depends not only on institutional preparedness but also on the ability of learners and educators to adapt to changing conditions. Studies conducted after the COVID-19 pandemic suggest that resilience is strengthened when digital access, digital competence, and institutional support operate together rather than in isolation (Bozkurt et al., 2022; Bond et al., 2024). These findings reinforce the view that educational continuity is shaped by multiple interacting factors and cannot be explained solely by access to technology or infrastructure.

Bringing these perspectives together provides a more grounded understanding of educational continuity. It shows that digital inequality, institutional capacity, and urban conditions are interconnected factors that shape how learning is sustained during disruption. Drawing on these perspectives, the study puts forward a conceptual model that connects these elements within a crisis-affected setting.

2.2 Previous Findings

Existing research highlights the growing importance of maintaining educational continuity during disruption, but it often examines key dimensions separately. Studies on urban resilience emphasize the need to sustain essential services and maintain system functionality during crises, yet they rarely address education as a core system (Hassankhani et al., 2021; Liu et al., 2021; Meerow et al., 2016).

At the same time, research on digital learning tends to focus on access, participation, and outcomes without fully situating these within broader urban and infrastructural conditions (OECD, 2020; UNESCO, 2021; Selwyn, 2021; Bozkurt et al., 2022; Bond et al., 2024).

Research on digital inequality shows that access is not a simple binary issue. Differences in internet reliability, device suitability, and digital skills significantly affect students' ability to engage in online learning (Van Deursen & Van Dijk, 2019; van Dijk, 2020). In practice, students with unstable connections or limited access to appropriate

devices experience frequent interruptions, which can reduce concentration, participation, and academic progress (Czerniewicz et al., 2020; Dhawan, 2020). These challenges are further influenced by the home environment, levels of parental support, and broader socio-economic conditions (Selwyn, 2021; Liu et al., 2021).

Recent studies have also highlighted the importance of reliable and consistent access to digital resources. Beyond device ownership and internet availability, differences in connectivity quality, learning environments, and digital competence can significantly influence students' opportunities to participate and succeed in online learning (Bond et al., 2024; Bozkurt et al., 2022). These findings suggest that digital inequality continues to evolve and may be experienced differently across educational and social contexts.

The role of teachers and institutions adds another important layer. When educators are confident in using digital tools and platforms, they can mitigate some of the barriers faced by students and support more stable learning experiences (Martin et al., 2020; World Bank, 2021). In contrast, limited institutional support, insufficient training, and lack of preparedness can amplify existing inequalities. Research on education system resilience confirms that institutions with stronger digital infrastructure and trained staff are better able to maintain continuity, while those with limited preparation experience greater disruption and reduced student engagement (Czerniewicz et al., 2020; Liu et al., 2021; Motz et al., 2023).

However, much of this literature is based on relatively stable contexts. It often assumes that once access is provided, learning systems can function effectively. This assumption becomes problematic in environments where infrastructure itself is unstable. In such contexts, digital inequality extends beyond access and reflects the extent to which learning conditions can actually support sustained engagement and meaningful participation (Van Deursen & Van Dijk, 2019).

A further limitation is the lack of regionally grounded research. Most studies focus on Europe, North America, and parts of Asia, while crisis-affected urban environments remain underrepresented. In cities such as Beirut, where economic and infrastructural instability persist, digital learning is not a temporary adjustment but an ongoing condition. Understanding how education operates in such settings requires closer attention to local realities rather than relying solely on models developed in more stable environments (UNESCO, 2021; Zhao et al., 2024).

2.3 Contribution to Knowledge

This study contributes to the literature by examining educational continuity through the combined perspectives of digital inequality, urban resilience, and education system resilience. While previous studies have explored these areas individually, relatively little attention has been given to how they interact in contexts where disruption and instability are part of everyday life. By bringing these perspectives together, the

study provides a more integrated understanding of the factors that influence learning continuity in crisis-affected environments.

A key contribution of the study is its focus on infrastructure instability as an important dimension of educational continuity. Existing research on digital inequality has largely emphasized access to devices, internet connectivity, and digital skills. The findings of this study suggest that the stability of these resources is equally important. In contexts where electricity outages and internet disruptions occur frequently, access alone does not guarantee meaningful participation in learning. This perspective extends current discussions of digital inequality by highlighting the role of infrastructure conditions in shaping educational experiences.

The study also contributes by introducing the Adaptive Educational Continuity under Infrastructure Instability framework. The framework provides a way of understanding how educational continuity is maintained when stable learning conditions cannot be assumed. Rather than viewing continuity as a direct outcome of institutional preparedness or technological access, the framework emphasizes the interaction between digital access, digital skills, infrastructure conditions, and students' responses to disruption. In doing so, it offers a perspective that helps explain how learning can continue even in highly unstable environments.

Another contribution lies in the study's examination of the relationship between continuity and learning. Much of the existing literature focuses on maintaining participation and access during periods of disruption. The findings suggest that remaining connected does not necessarily lead to meaningful learning outcomes. Students may continue attending classes and completing tasks while still experiencing fragmented learning due to unstable conditions. This distinction adds an important dimension to discussions of educational continuity and highlights the need to consider learning quality alongside participation.

Finally, the study contributes empirical evidence from Beirut, a context that remains underrepresented in research on digital learning and educational resilience. Much of the existing literature is based on relatively stable educational systems, whereas this study provides insight into how students experience learning under persistent economic and infrastructural challenges. By documenting these experiences, the study broadens current understanding of educational continuity and offers insights that may be relevant to other crisis-affected settings facing similar conditions.

Taken together, these contributions extend current discussions of digital inequality, resilience, and educational continuity by demonstrating that learning during disruption is shaped not only by access to technology but also by the broader structural conditions in which education takes place. The study therefore provides both a conceptual and practical contribution to understanding how education can be sustained in environments characterized by ongoing uncertainty and instability.

3. Methodology

3.1 Research Design

Design type: Mixed-methods case study

Justification. This study adopts a mixed-methods case study design to examine how digital inequality influences students' ability to sustain learning during periods of disruption in Greater Beirut. The case study approach makes it possible to explore the phenomenon within its real-life context, where economic instability and infrastructural challenges directly shape educational experiences.

Both quantitative and qualitative data were collected concurrently. Each dataset was first analyzed independently and then brought together at the interpretation stage to provide a more complete understanding of the research problem (Creswell & Creswell, 2018). This approach allows the study to capture both measurable patterns in digital access and continuity, as well as the lived experiences behind those patterns.

The study is guided by a pragmatic paradigm, which supports the use of multiple methods when addressing complex, real-world issues. This perspective is particularly suitable for examining educational continuity in unstable environments, where no single method is sufficient to capture the full scope of the problem.

3.2 Participants

Table 1
Participant Characteristics

Characteristic	Value
Total N	197
Age range / Mean (SD)	15–24 (M = 19.2, SD = 2.3)
Gender (M / F / Other)	Male: 48%, Female: 52%
Education level	Grades 10–12 and University
Setting	School and University
Country / Region	Greater Beirut, Lebanon
Sampling strategy	Stratified purposive sampling

Note. N = 197. Percentages are based on the total sample. M = mean; SD = standard deviation.

Participants were selected using a stratified purposive sampling approach to ensure representation across different educational levels and learning environments. This allowed the study to capture variation in experiences between school and university students, while remaining focused on the same broader context.

Power Analysis

An a priori power analysis was conducted using G*Power. Assuming a medium effect size ($f^2 = 0.15$), an alpha level of 0.05, and a desired statistical power of 0.80, the minimum required sample size was 92 participants. The final sample exceeded this threshold, providing sufficient statistical power for the analyses conducted in this study.

3.3 Instruments

Table 2
Instruments and Reliability

Instrument Name	What It Measures	No. Items	Scale	α This Study	α Source
Digital Access Scale	Internet reliability, device suitability, digital skills	12 items	Likert (1–5)	0.78–0.86	Adapted
Educational Continuity Scale	Attendance, task completion, perceived progress	9 items	Likert (1–5)	0.80+	Adapted

Note. α = Cronbach's alpha. All values indicate acceptable internal consistency. Scales were adapted from existing instruments.

The instruments were selected and adapted to reflect key dimensions of digital access and educational continuity relevant to the study context. Reliability analysis showed acceptable internal consistency across all scales, indicating that the measures were suitable for capturing the intended constructs.

3.4 Intervention / Program Description

Not applicable. This study does not include an experimental or intervention-based component. Instead, it examines naturally occurring learning conditions during periods of disruption, allowing for an analysis of how students respond to existing constraints in real-world settings.

3.5 Data Collection Procedures

Data were collected over a six-week period. First, an online survey was distributed to students to gather quantitative data on digital access, digital skills, and educational continuity. The survey format ensured accessibility and allowed students to participate despite ongoing infrastructural constraints. Second, semi-structured interviews were conducted with teachers and administrators. Each interview lasted between 30 and 45 minutes and focused on institutional responses, challenges, and support mechanisms related to digital learning. Third, three student focus groups were conducted, each lasting between 45 and 60 minutes. These discussions provided deeper insight into students' lived experiences, including the strategies they used to cope with unstable learning conditions. All data were collected online to accommodate the existing context and to ensure consistent participation across different locations.

3.6 Data Analysis

Descriptive statistics were used to summarize patterns in digital access and educational continuity. Pearson correlation analysis was conducted to examine the relationships between key variables and to address the first research question (RQ1). This step provided an initial understanding of how different aspects of digital access relate to students' ability to maintain continuity.

Multiple regression analysis was then performed to assess the predictive effects of internet reliability, device suitability, and digital skills on educational continuity (H1–H3), while controlling for contextual variables such as socioeconomic background and type of institution. This allowed the study to identify the relative contribution of each factor within a single model.

All analyses were conducted using SPSS (Version 26). Prior to running the regression, key assumptions—including linearity, normality, and multicollinearity—were checked to ensure the validity of the model.

Effect size was calculated using Cohen's f^2 to assess the practical significance of the findings, following established guidelines (Cohen, 1988). Socioeconomic background and type of institution were included as control variables to account for potential contextual influences. The study focused on the direct effects of the variables examined. However, the findings suggest that digital access, digital skills, and educational continuity are closely intertwined, pointing to relationships that could be explored in greater depth in future research. These patterns are interpreted with caution and are used to inform the discussion rather than to establish causal claims.

4. Results

4.1 Descriptive Statistics

Table 3
Descriptive Statistics

Variable	N	Mean (M)	Std Dev (SD)	Min	Max
Internet reliability	150	3.10	0.85	1	5
Device suitability	150	3.25	0.90	1	5
Digital skills	150	3.60	0.70	1	5
Educational continuity	150	3.20	0.88	1	5

Note. Descriptive statistics indicate moderate levels of digital access and educational continuity among participants.

4.2 Inferential Statistics

RQ1 / H1 Result. Pearson correlation analysis showed a positive relationship between internet reliability and educational continuity, $r(148) = .33$, $p < .001$.
RQ2 / H2 Result. Device suitability was positively associated with educational continuity, $r(148) = .37$, $p < .001$.
RQ3 / H3 Result. Digital skills showed the strongest relationship with educational continuity, $r(148) = .41$, $p < .001$, indicating that students who were more comfortable using digital tools were better able to keep up with their learning despite the challenges they faced.

Multiple Regression Analysis
Table 4
Multiple Regression Predicting Educational Continuity

Predictor	β	*t*	*p*
Internet reliability	.18	2.05	.041
Device suitability	.24	2.70	.008

Predictor	β	*t*	*p*
Digital skills	.31	3.45	.001
Socioeconomic background	.07	1.01	.312
Type of institution	.05	0.79	.428

Note. β = standardized regression coefficient. The model was statistically significant, $F(5, 144) = 14.82$, $p < .001$, $R^2 = .34$. Socioeconomic background and type of institution were included as control variables.

Model Summary:

$F(5, 144) = 14.82$, $p < .001$, $R^2 = .34$. The model is statistically significant and explains a meaningful share of the variation in educational continuity. Among the predictors, digital skills stand out as the strongest, followed by device suitability and then internet reliability. While the analysis focuses on direct effects, the pattern of results points to a more layered relationship. Access alone does not seem to guarantee continuity. These patterns explain why some students are better able to maintain engagement than others under similar conditions. Rather than access alone making the difference, what seems to matter most is how effectively students are able to use it. In this sense, digital skills help explain why some students manage to stay on track while others struggle, even when they face similar conditions.

A closer look at school and university students also reveals some differences. University students tend to report stronger digital skills and more steady engagement, whereas school students experience more frequent interruptions. This suggests that age, experience, and independence play a role in how students respond to unstable learning environments, shaping their ability to cope with disruption and maintain continuity.

4.3 Qualitative Findings from Interviews and Focus Groups

The qualitative findings provided additional insight into how students, teachers, and administrators experienced educational continuity during periods of disruption. Three recurring themes emerged from the interviews and focus group discussions: infrastructure instability, adaptive learning strategies, and the importance of digital skills.

Theme 1: Infrastructure Instability as a Daily Challenge

Participants consistently described internet interruptions and electricity outages as major obstacles to learning. Students explained that disruptions often occurred during live

classes, assessments, and assignment submissions, making it difficult to maintain a consistent learning routine. Teachers also noted that unstable infrastructure affected student participation and limited opportunities for meaningful interaction.

> **One student** explained, "Sometimes I could attend a class, but I was never sure if the internet would stay connected until the end. It made it difficult to focus on learning."

Theme 2: Learning Through Adaptation

Despite these challenges, many participants described developing strategies to continue learning. Students reported downloading materials in advance, sharing internet access with family members, using mobile data when available, and adjusting study schedules around electricity availability.

> **A teacher** noted, "Students became very creative in finding ways to stay connected. They often adapted more quickly than the system itself."

Theme 3: Digital Skills as a Source of Resilience

Participants frequently emphasized the importance of digital skills in helping students manage disruption. Students who were comfortable using different platforms and digital tools reported fewer difficulties maintaining participation and completing academic tasks. Teachers and administrators similarly viewed digital competence as an important factor supporting continuity.

An administrator commented, "Access is important, but knowing how to use available resources effectively often makes the difference between falling behind and staying engaged."

Overall, the qualitative findings complement the quantitative results by showing that educational continuity was shaped not only by access to technology but also by students' ability to adapt and make effective use of available resources under difficult conditions.

4.4 Effect Sizes

The regression model showed a large practical effect ($F(5, 144) = 14.82$, $p < .001$, Cohen's $f^2 = 0.52$), indicating that the digital access variables collectively had a substantial influence on educational continuity. This large effect size suggests that the

observed relationships were not only statistically significant but also educationally meaningful.

4.5 Learning Gain

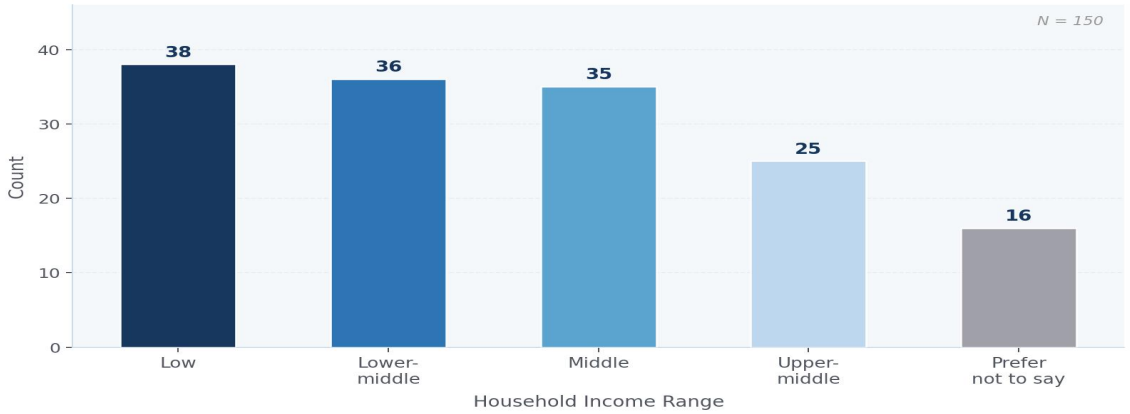
Not applicable. This study does not include a pre–post or intervention-based design, and therefore learning gain measures (e.g., pre-test/post-test comparisons) were not calculated. Educational continuity was assessed through cross-sectional measures of participation, task completion, and perceived academic progress.

4.6 Tables and Figures

Table 1 provides an overview of the participants' demographic and educational characteristics. Table 2 outlines the instruments used in the study together with their reliability measures. Table 3 presents descriptive statistics for the main variables, while Table 4 reports the results of the multiple regression analysis examining the influence of internet reliability, device suitability, and digital skills on educational continuity.

Figure 1 highlights the infrastructure-related challenges experienced during online learning. Figure 2 shows the types of devices most commonly used by participants for learning. Figure 3 presents the Adaptive Educational Continuity under Infrastructure Instability framework developed from the study findings. All tables and figures are numbered consecutively and cited in the text.

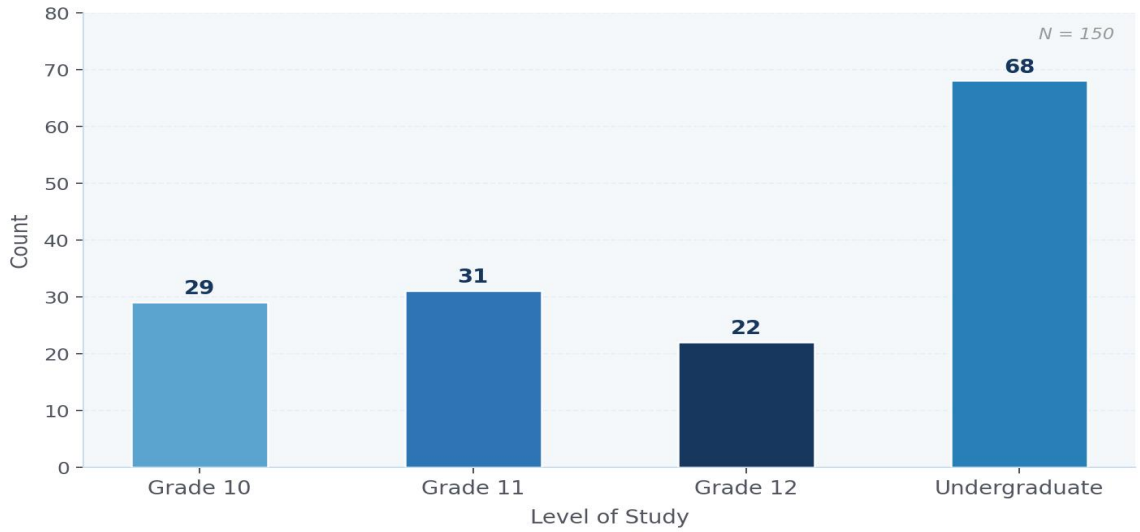
Figure 1
Infrastructure-Related Challenges During Online Learning



Note. Internet interruptions and electricity cuts represent the most commonly reported barriers to stable participation.

These patterns suggest that online learning operates within unstable technical conditions, requiring students to adapt continuously in order to remain engaged.

Figure 2
Distribution of Main Device Used for Learning



Note. Laptops are the most commonly used devices, followed by smartphones, while tablets are used less frequently.

4.7 Proposed Framework: Adaptive Educational Continuity under Infrastructure Instability

Building on the quantitative and qualitative results presented above, a conceptual framework was formulated to explain how educational continuity is maintained under conditions of ongoing infrastructure instability. Much of the existing research tends to assume that educational continuity depends mainly on stable systems—reliable infrastructure, institutional preparedness, and consistent access to digital tools. However, the findings of this study suggest something different. In contexts such as Beirut, where instability is not temporary but ongoing, continuity does not come from stability. Instead, it is maintained through constant adjustment on the part of students themselves.

To better explain this, the study introduces the idea of Adaptive Educational Continuity under Infrastructure Instability. This concept shifts the focus from systems to people. It looks at how students manage to keep learning even when the conditions around them are unpredictable.

In this model, infrastructure instability—especially unreliable internet and frequent electricity cuts—is not just a background issue; it directly shapes how learning takes place. These conditions limit access, interrupt participation, and make it difficult to follow a consistent learning routine. Research on the digital divide has already shown that access is uneven and that quality matters just as much as availability (Van Deursen & Van Dijk, 2019; van Dijk, 2020). What this study adds is that in unstable environments, even access itself becomes uncertain, which changes how learning is experienced on a daily basis.

Within this setting, digital skills become especially important. Students who are more comfortable using technology are better able to cope with disruptions. They find ways to reconnect, switch tools, manage files, and keep up with tasks even when things do not work as expected. In this sense, digital skills are not only technical abilities; they act as a form of practical resilience that helps students continue learning under pressure (Selwyn, 2021).

At the same time, device suitability also plays a role. Students working on appropriate devices—such as laptops rather than small mobile phones—are generally able to engage more effectively with their coursework. This affects not only access, but also the quality of participation and the ability to complete tasks in a meaningful way (Czerniewicz et al., 2020).

An important point that emerges from this model is the difference between simply staying connected and actually learning. Many students remain present in online classes, attend sessions, or submit assignments. However, this does not always mean that learning is taking place in a deep or consistent way. Under unstable conditions, attention is often interrupted, and understanding becomes uneven. This supports earlier arguments that

access and participation alone do not guarantee meaningful learning outcomes (OECD, 2020; UNESCO, 2021).

Overall, Adaptive Educational Continuity under Infrastructure Instability presents continuity as something conditional rather than guaranteed. It shows that in crisis-affected environments, learning is sustained through the interaction between difficult structural conditions and students' ability to adapt. In doing so, the model extends existing work on the digital divide by emphasizing stability as a key dimension, and it also reconsiders resilience by showing that it may shift from institutions to individuals when systems are under strain (Czerniewicz et al., 2020; Liu et al., 2021; Motz et al., 2023; Meerow et al., 2016).

As illustrated in Figure 3, unstable infrastructure first affects digital access, which then influences students' digital skills and, in turn, shapes their ability to maintain educational continuity.

Stated more precisely, the framework operates across three interconnected levels, each represented as a tier in Figure 3.

Level 1. Structural conditions, consists of infrastructure instability itself—the electricity outages and internet disruptions that form the backdrop against which learning must take place. This level is treated as a precondition rather than a variable to be measured directly, since it is the source from which the inequalities described in the next level emerge.

Level 2. Digital access, captures the resources through which students attempt to participate despite instability: internet reliability and device suitability. Both were significant predictors of educational continuity in the regression model (internet reliability, $\beta = .18$, $p = .041$; device suitability, $\beta = .24$, $p = .008$), confirming that access remains necessary even when it is not sufficient on its own.

Level 3. Adaptive capacity, is represented by digital skills, which emerged as the strongest predictor in the model ($\beta = .31$, $p = .001$) and the strongest bivariate correlate of continuity ($r(148) = .41$, $p < .001$). This level is what gives the framework its name: it is the layer at which students convert whatever access they have, however unstable, into sustained participation. The pattern of effect sizes across the three predictors—internet reliability, then device suitability, then digital skills—reflects an underlying logic in which adaptive capacity carries more explanatory weight than access alone.

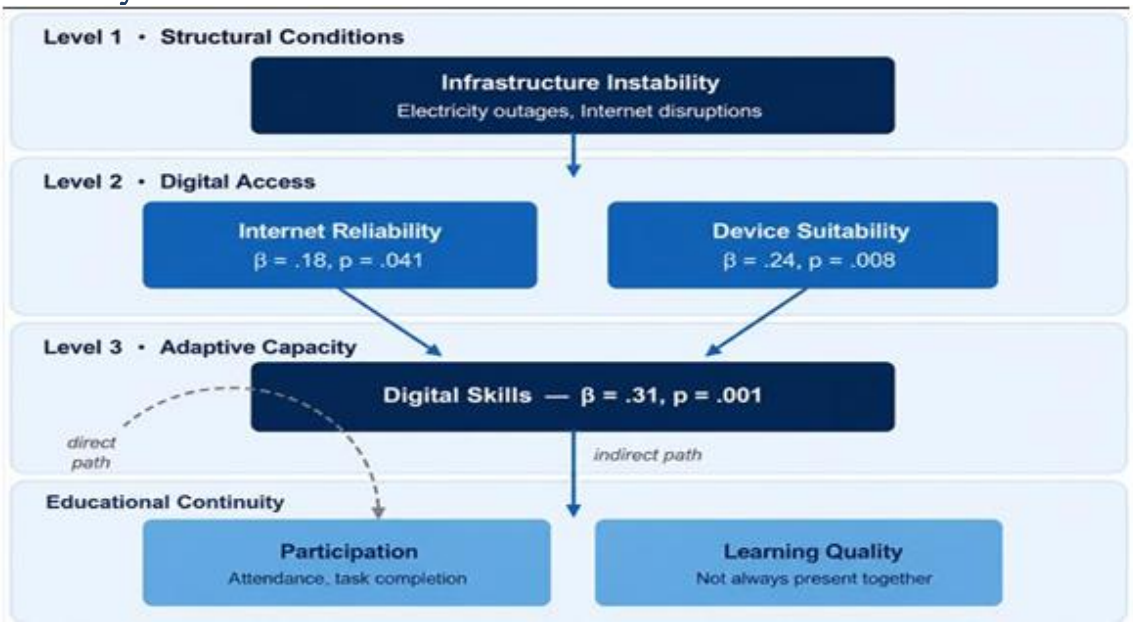
Educational continuity in this study was shaped by the combined influence of infrastructure conditions, digital access, and digital skills. Infrastructure instability formed the backdrop against which learning took place, while access to reliable internet and suitable devices provided the means for participation. At the same time, digital skills helped students make effective use of the resources available to them. The findings showed that all three factors contributed significantly to educational continuity, with digital skills emerging as the strongest predictor ($\beta = .31$, $p = .001$), followed by device suitability ($\beta = .24$, $p = .008$) and internet reliability ($\beta = .18$, $p = .041$). Together, these

variables explained a substantial proportion of the variation in educational continuity (R^2 = .34, $F(5,144) = 14.82$, $p < .001$; Cohen's $f^2 = 0.52$), highlighting the importance of both access and students' ability to adapt under unstable learning conditions.

Finally, the framework deliberately separates educational continuity into two components—participation and learning quality—rather than treating it as a single outcome. This separation reflects a recurring pattern in the qualitative findings: students frequently sustained participation, measured through attendance and task completion, without a corresponding gain in learning quality, since attention and understanding were repeatedly interrupted by unstable conditions. The framework therefore presents continuity as conditional in two senses at once—conditional on students' adaptive capacity, and conditional on whether sustained participation actually translates into sustained learning.

Figure 3

Conceptual model of Adaptive Educational Continuity under Infrastructure Instability.



Note. The model proposes that educational continuity is shaped by the combined influence of infrastructure conditions, digital access, and digital skills. Digital skills emerged as the strongest contributor to sustained participation under unstable conditions. Continuity is shown as comprising both participation and learning quality because the two did not always develop in the same way.

Taken together, the quantitative and qualitative findings provide convergent evidence supporting the feasibility and educational value of the Ignition Method across the participating school contexts.

5. Discussion

5.1 Interpretation of Findings

The findings can be more clearly understood when considered in relation to the model of Adaptive Educational Continuity under Infrastructure Instability presented in Figure 3. They suggest that continuity is not rooted in stable infrastructure, but in how students respond to repeated disruption. In this context, learning does not continue because conditions are reliable; rather, it is sustained through students' ongoing efforts to adjust to whatever resources are available at a given moment. The strong role of digital skills further highlights this point, emphasizing the importance of students' own abilities when the surrounding environment cannot be relied on.

This pattern is particularly visible in Beirut. Continuity is present, but it takes place under conditions that are far from stable. What stands out is that it depends less on consistent institutional support and more on students' ongoing efforts to cope with interruptions. Rather than reflecting strong systems, continuity here seems to grow out of constant adjustment, where students carry much of the responsibility for keeping their learning on track.

The regression results reinforce this interpretation. Digital skills emerge as the strongest predictor of educational continuity, followed by device suitability and then internet reliability. This order is important. It suggests that access alone does not fully explain continuity. What seems to matter most is whether students are able to make effective use of what they have. In this sense, digital skills appear to strengthen students' ability to make effective use of available resources, helping explain why some students maintain continuity more successfully than others under similar conditions.

The size of the effect (Cohen's $f^2 = 0.52$) further highlights the weight of these factors. It shows that digital access and related capabilities have a strong, practical influence on whether students are able to stay engaged. Simply put, students who have suitable tools and know how to use them are in a much better position to continue learning, even when conditions are unstable.

Looking more closely at different groups adds another layer to this picture. Differences between school and university students help clarify how continuity is maintained. University students tend to show stronger digital skills and more stable

engagement, while school students face more frequent interruptions. This may be linked to differences in independence and familiarity with digital tools. Older students are often better able to manage disruptions on their own, while younger students may rely more on structured support. This reinforces the idea that continuity is shaped not only by access, but also by students' ability to adapt to changing conditions.

At the same time, the findings draw a clear line between participation and meaningful learning. Many students remain present in online settings—they attend sessions and complete tasks—but this does not always translate into real academic progress. Under unstable conditions, learning often becomes fragmented, with interruptions affecting focus and continuity of understanding. Being present, in other words, does not necessarily mean learning effectively.

Taken together, these results suggest that educational continuity in this context is conditional and uneven. It is shaped by the interaction between structural limitations and individual capacity. Continuity exists, but it does not look the same for all students, nor does it guarantee meaningful learning outcomes.

5.2 Comparison with Previous Research

The findings of this study are consistent with previous research showing that access alone does not guarantee meaningful learning outcomes. Studies by OECD (2020), Czerniewicz et al. (2020), and Selwyn (2021) emphasize that the quality and conditions of access play an important role in shaping students' learning experiences. The present study supports this view but also suggests that in unstable environments, access itself cannot always be assumed. When internet connectivity and electricity supply are unreliable, students face challenges that extend beyond the simple availability of digital tools.

Much of the existing literature on digital learning assumes that once students have access to devices and internet connectivity, educational continuity can be maintained. However, the findings indicate that this assumption does not fully reflect the realities of crisis-affected settings. In environments where infrastructure is unstable, access becomes inconsistent, and students must continually adjust to disruptions that affect their ability to participate and learn effectively.

The importance of infrastructure reliability also reinforces previous work on the digital divide. Researchers such as van Dijk (2020) and Selwyn (2021) argue that digital inequality involves not only access but also the quality and usability of digital resources. The findings of this study extend that argument by highlighting instability as an additional dimension of inequality. Frequent electricity outages and internet interruptions do not simply reduce access; they shape the entire learning experience and make sustained engagement more difficult.

The findings also offer a different perspective on education system resilience. Previous studies (Czerniewicz et al., 2020; Liu et al., 2021; Motz et al., 2023) emphasize the role of institutional preparedness in supporting educational continuity during disruption. While institutional support remains important, the results suggest that when such support is limited, students often assume a greater share of responsibility for maintaining their learning. In this context, continuity depends not only on the capacity of educational institutions but also on the ability of learners to adapt to changing circumstances. This points to a broader understanding of resilience, one that includes both institutional support and individual adaptation.

Another important point concerns the relationship between educational continuity and meaningful learning. While many studies focus on maintaining access and participation, the present findings suggest that these factors alone do not guarantee positive learning outcomes. Students may remain connected and continue participating in online activities, yet their learning can still be fragmented by repeated interruptions and unstable learning conditions. This highlights the need to distinguish between continuity of participation and continuity of learning.

The findings also suggest that educational continuity in crisis-affected environments cannot be explained solely by access to technology or socioeconomic status. Although previous research has identified income and resource availability as important factors shaping digital inequality (van Dijk, 2020; OECD, 2020), the results indicate that widespread infrastructure instability may influence students across different backgrounds in similar ways. In contexts where internet disruptions and electricity shortages are persistent, broader structural conditions become an important part of the explanation. This suggests that understanding educational continuity requires attention not only to individual resources but also to the wider conditions that shape students' opportunities to learn and participate effectively.

5.3 Theoretical Implications and Model Contribution

The findings contribute to the theoretical frameworks outlined in Section 2.1 by bringing together perspectives from digital divide theory, urban resilience, and education system resilience. A key contribution of the study lies in moving the discussion beyond describing the challenges associated with digital inequality and toward a deeper understanding of how educational continuity is maintained under conditions of disruption.

First, the findings support digital divide theory by showing that inequality extends beyond access to technology. The results indicate that the quality, usability, and stability of digital resources are equally important in shaping students' learning experiences. In particular, the study highlights infrastructure instability as a central factor influencing access and participation.

Second, the findings offer a different perspective on urban resilience. Rather than viewing resilience primarily as a system-level characteristic, the results suggest that resilience may also be expressed through the actions of individuals. In this context, educational continuity was often sustained through students' efforts to adapt to changing circumstances rather than through consistent institutional support.

Third, the study extends education system resilience frameworks by demonstrating that institutional preparedness and support are not always sufficient or consistently available in crisis-affected environments. When these forms of support are limited, students become increasingly dependent on their own skills and adaptive capacity to maintain engagement with learning.

Taken together, the findings show how digital inequality, institutional conditions, and infrastructure instability interact to shape educational continuity. More broadly, the proposed Adaptive Educational Continuity under Infrastructure Instability framework offers a different perspective on how learning is sustained in crisis-affected environments. The findings suggest that educational continuity cannot always be explained by the presence of stable infrastructure or strong institutional support. In contexts where disruption is an ongoing reality, students often rely on their ability to adapt to changing conditions in order to continue learning. The framework highlights the interaction between structural challenges and individual capacity, showing how continuity is shaped by both the resources available to learners and the ways they respond to limitations and uncertainty. By bringing these dimensions together, the study extends existing discussions of digital inequality and resilience and contributes to a deeper understanding of how education can be maintained under conditions of persistent instability.

6. Conclusion

6.1 Summary of Findings

This study examined the relationship between digital access, digital skills, and educational continuity among secondary school and university students in Beirut during a period of ongoing infrastructure instability. The findings indicate that both digital access and digital skills play an important role in supporting educational continuity, although their influence is shaped by the broader conditions in which students learn. Reliable internet connectivity, suitable devices, and confidence in using digital technologies were all associated with stronger educational engagement and continuity.

The results also revealed the significant impact of infrastructure instability on students' learning experiences. Frequent electricity outages and internet disruptions created barriers that affected participation, access to learning resources, and the overall learning process. These challenges often extended beyond individual circumstances and

reflected broader structural conditions that influenced students across different backgrounds.

At the same time, the findings showed that students were not simply passive recipients of these conditions. Many developed practical ways of responding to disruption, adjusting their study routines and making use of available resources to maintain their engagement with learning. This highlights the importance of considering both structural constraints and individual responses when examining educational continuity in crisis-affected settings.

Drawing on these findings, the study proposed the Adaptive Educational Continuity under Infrastructure Instability framework. The framework provides a way of understanding how educational continuity is shaped through the interaction between digital access, digital skills, infrastructure conditions, and students' capacity to navigate ongoing challenges. It offers a perspective that moves beyond simple measures of access and draws attention to the complex realities that influence learning during periods of instability.

More broadly, the study highlights the challenges of sustaining education in environments where disruption has become part of everyday life. The findings suggest that educational continuity is influenced not only by access to technology but also by the wider conditions in which learning takes place. By examining these issues within the context of Beirut, the study contributes to a better understanding of how education can be maintained during periods of uncertainty and disruption. It also underscores the importance of developing policies and support systems that respond to students' realities and promote more equitable and sustainable learning opportunities.

6.2 Educational Implications

The findings of this study have important implications for educational practice, institutional planning, and policy development. They suggest that maintaining educational continuity during periods of disruption requires more than simply providing access to digital technologies. While reliable internet connections and appropriate devices remain essential, students also need the skills, support, and learning conditions that enable them to use these resources effectively.

For teachers, the findings highlight the value of adopting flexible approaches that can accommodate interruptions and changing circumstances. Providing alternative learning materials, recorded lessons, and multiple options for communication and assessment may help students remain engaged when access conditions are unstable.

For curriculum designers, the results emphasize the importance of developing learning materials that can be accessed across different devices and varying levels of connectivity. Designing resources that are adaptable, mobile-friendly, and accessible

under challenging conditions may help reduce barriers to participation and support more consistent learning experiences.

For educational institutions, the findings point to the need for stronger support systems that extend beyond technology provision. Technical assistance, digital literacy initiatives, and clear contingency plans can help both students and teachers respond more effectively when disruptions occur. Building institutional preparedness may reduce the educational impact of future crises and contribute to more resilient learning environments.

At the policy level, the study highlights the importance of addressing infrastructure challenges as part of broader educational planning. Efforts to improve educational continuity should consider not only access to technology but also the wider conditions that shape students' opportunities to learn. Investments in digital infrastructure, equitable access initiatives, and long-term preparedness strategies may help strengthen educational resilience and reduce the effects of digital inequality in crisis-affected contexts.

Taken together, the findings suggest that educational continuity is best supported through a combination of reliable infrastructure, effective institutional support, and opportunities for students to develop the skills needed to navigate changing learning conditions. Such an approach may contribute to more equitable and sustainable educational systems, particularly in environments where instability remains an ongoing challenge.

6.3 Research Output and Practical Impact

This study produces a conceptual framework, Adaptive Educational Continuity under Infrastructure Instability, which explains how students maintain learning continuity in environments characterized by unreliable infrastructure and unequal digital access. The framework highlights the interaction between digital access, digital skills, and educational continuity, emphasizing the role of individual adaptation when institutional and infrastructural support is limited.

The practical value of this framework lies in its potential to help educational institutions better understand the conditions that support learning during periods of disruption. Rather than focusing solely on access to technology, the findings suggest that digital skills and adaptive capacity play an equally important role in sustaining educational participation. This perspective may assist schools, universities, and educational organizations in designing support systems that respond more effectively to the realities faced by students in unstable environments.

The study also offers evidence that educational continuity should be considered an important component of urban and institutional resilience. By demonstrating how infrastructure instability affects learning experiences, the findings provide useful insights for policymakers, educational leaders, and development organizations seeking to reduce digital inequality and strengthen preparedness for future disruptions. Although the study focuses on Beirut, the framework may be relevant to other crisis-affected settings where educational systems operate under similar constraints.

6.4 Limitations

Limitation 1. This study focuses on a single context, Beirut, which may limit how far the findings can be applied to other settings. While the case provides valuable insight into learning under unstable conditions, different regions may experience these challenges in different ways. The proposed Adaptive Educational Continuity under Infrastructure Instability framework was developed from evidence gathered in this context and has not yet been examined in other educational environments. Further research is needed to explore its applicability across different settings and populations.

Limitation 2. Much of the quantitative data was based on students' self-reported experiences and perceptions. While these responses provide valuable insight into how students experienced learning under unstable conditions, they may not always reflect actual academic performance or learning outcomes. Future studies could complement self-reported data with objective measures such as academic records, attendance data, or learning assessments.

Limitation 3. The study distinguished between educational continuity and learning quality largely through participants' experiences and qualitative accounts. Although this helped provide a richer understanding of how students navigated disruption, learning quality was not measured as a separate construct. Future research could examine learning quality directly to better understand how participation and learning outcomes relate to one another in unstable educational environments.

Limitation 4. The study is based on a cross-sectional design, capturing experiences at one point in time. As a result, it does not show how learning conditions or student responses may change as situations evolve.

Limitation 5. The quantitative analysis focused on correlation and multiple regression techniques to identify the main factors associated with educational continuity. While these methods were appropriate for the aims of the study, they do not fully capture the

more complex relationships that may exist among the variables. Future research could explore these relationships in greater depth using additional analytical approaches.

Limitation 6. The study does not include an intervention or experimental component. This means it cannot assess how specific strategies, teaching approaches, or institutional support might actively improve educational continuity under unstable conditions.

6.5 Future Research Directions

Direction 1. Future research could examine similar questions across different regions to better understand how digital inequality operates under varying infrastructural and socioeconomic conditions. Such studies could also help assess the applicability of the Adaptive Educational Continuity under Infrastructure Instability framework beyond the Beirut context.

Direction 2. Longitudinal studies would help track how students' learning experiences and outcomes develop over time, especially in environments where instability is ongoing rather than temporary.

Direction 3. Intervention-based research could explore how different forms of support—such as teaching strategies, institutional policies, or digital tools—can improve continuity and learning outcomes in practice.

Direction 4. Future studies could examine the relationships among digital access, digital skills, infrastructure conditions, and educational continuity using more advanced analytical approaches. Such work may provide a deeper understanding of how these factors interact and influence educational experiences in unstable learning environments.

Direction 5. Future work could combine longitudinal and intervention-based approaches to better understand not only how students adapt over time, but also how targeted support can strengthen learning in unstable environments.

DECLARATIONS

Author Contributions: Author contributions are reported using the CRediT (Contributor Roles Taxonomy) framework.

CRediT Role	Contributor
Conceptualization	R.A.M.
Methodology	R.A.M.
Data Collection	R.A.M.
Formal Analysis	R.A.M.
Writing – Original Draft	R.A.M.
Writing – Review & Editing	R.A.M.
Supervision	R.A.M.

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Ethics Statement: This study was conducted in accordance with the ethical standards of the Islamic University of Lebanon. Informed consent was obtained from all participants. No personally identifiable information was collected or reported.

AI DISCLOSURE

In preparing this manuscript, the author used artificial intelligence (AI)-assisted writing tools (for the purposes of language editing, grammar checking, and structural

clarity. All research design, data collection, analysis, interpretation, and intellectual content were conducted entirely by the author. The AI tools did not contribute to the conception, methodology, findings, or conclusions of this study. The author takes full responsibility for the integrity and accuracy of the work.

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