

# STRUCTURAL CAUSES OF THE DIGITAL DIVIDE AND ITS LONG-TERM CONSEQUENCES FOR ACADEMIC ACHIEVEMENT

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## ABSTRACT

The rapid digitalization of education has reshaped learning environments but also exacerbated longstanding social inequities, creating a multidimensional digital divide. This study examines the structural determinants of digital exclusion, differences in access, skills, and usage, and evaluates their influence on students' academic performance. Using a mixed-methods design, we analyze micro-level data from the 2018 Program for International Student Assessment (PISA) alongside a thematic synthesis of recent case studies. Quantitative results show a strong positive association ( $p < 0.01$ ) between a composite Digital Access Index and achievement in mathematics, reading, and science, independent of socioeconomic status. The qualitative findings reveal three recurring determinants: socioeconomic and infrastructural constraints, disparities in teacher digital preparedness, and variations in sociocultural and digital capital. Integrating both strands of evidence, the study demonstrates how digital exclusion contributes to persistent educational disadvantages and constrains long-term opportunities in higher education and the labor market. Our study that addresses the digital divide requires coordinated reforms targeting infrastructure, digital competency development, and equitable pedagogical design to prevent the further entrenchment of digital stratification.

**Keywords:** *C++*, *Code Reusability*, *Template Programming*, *Generic Programming*, *Function Templates*, *Class Templates*, *Standard Template Library (STL)*, *Compile-Time Polymorphism*, *Template Metaprogramming*.

## 1. INTRODUCTION

The 21st century has been defined by a rapid digital revolution that has fundamentally reshaped economies, societies, and educational landscapes. Information and Communication Technologies (ICT) are no longer supplemental tools but are central to curriculum delivery, knowledge acquisition, and the cultivation of critical thinking and problem-solving skills [1]. Within this context, the digital divide emerges as a fundamental fault line.

This study investigates how structural inequities in digital access, skills, and support, collectively known as the digital divide, systematically undermine academic achievement and constrain long-term socioeconomic opportunities. While the

correlation between technology access and educational outcomes is acknowledged, a critical gap remains in understanding the precise mechanisms through which the divide's structural determinants translate into academic disadvantage and its enduring consequences. To address this gap, we employ a mixed-methods approach to analyze both the large-scale patterns and the contextual realities of digital exclusion, aiming to provide a synthesized framework that links infrastructural, pedagogical, and sociocultural barriers to students' immediate performance and future life chances. This inquiry is urgent because the digitalization of education, accelerated by the COVID-19 pandemic [2], has made digital inclusion a prerequisite for equitable participation in learning, not a supplementary advantage.

This disparity, known as the "digital divide," has evolved from a binary concept of hardware access into a nuanced, multi-level construct. Contemporary scholarship conceptualizes it as a phenomenon comprising: (1) the first-level divide (access to devices and connectivity), (2) the second-level divide (disparities in digital skills and literacies), and (3) the third-level divide (inequities in tangible outcomes derived from technology use) [3]. When these divides intersect with education, they pose a significant risk of academic underachievement for digitally disadvantaged populations.

Despite widespread recognition of the digital divide, its persistence as a structural problem within education systems remains a critical challenge. The core problem is that inequitable access to digital technologies, coupled with disparities in the skills to use them effectively and the capital to derive benefit from them, systematically translates into unequal educational outcomes. This is not merely a logistical issue but a fundamental driver of educational inequality. The problem is most severe for students already facing socioeconomic disadvantages, including those from low-income households, rural communities, and under-resourced schools. For these populations, digital exclusion acts as a compounding barrier, limiting their access to modern learning resources, hindering the development of essential 21st-century competencies, and consequently constraining their academic performance and future opportunities. Therefore, understanding the specific structural roots of this divide and their direct link to achievement gaps is essential for developing effective, targeted interventions.

Although existing literature establishes a correlation between access to technology and academic performance, a comprehensive analysis systematically linking the structural determinants of the divide to specific mechanisms of underachievement and their long-term consequences remains underexplored. This paper addresses this gap by investigating the following research questions:

1. What are the primary structural determinants of the digital divide in an educational context?
2. How do these determinants directly and indirectly contribute to academic underachievement?
3. What are the long-term socioeconomic consequences for students marginalized by the digital divide?

This study seeks to advance the field through several original contributions. Methodologically, it innovates by employing a sequential mixed-methods design that quantitatively establishes the independent effect of a composite Digital Access Index on core academic competencies using international PISA data, and then qualitatively unpacks the 'black box' of this relationship through a thematic synthesis of recent case studies. This integration allows us to move beyond correlation to explore causation and mechanism. Conceptually, it offers an original synthesized framework (Figure 1) that delineates three interlocking structural determinants, socioeconomic/infrastructural, pedagogical, and sociocultural, and traces their direct and indirect pathways to academic underachievement. In terms of scope, it explicitly connects these immediate educational impacts to their long-term consequences for higher education access and labor market segmentation, arguing for the digital divide as a key mechanism in the intergenerational reproduction of inequality. Thus, the study's originality resides in its integrated analysis of structure, process, and outcome across micro and macro levels.

The paper is structured as follows: Section 2 provides a review of the relevant literature. Section 3 outlines the mixed-methodology. Section 4 presents the results, and Section 5 discusses the long-term consequences and policy implications. Section 6 provides a concluding summary.

## 2. LITERATURE REVIEW

Initial research on the digital divide in the 1990s primarily focused on physical access to computers and the Internet, highlighting the gap between the "information-rich" and "information-poor" populations along traditional lines of socioeconomic status, race, and geography [4].

This study identifies three primary structural determinants of the educational digital divide: socioeconomic and infrastructural constraints (device access, broadband quality, and study environment), pedagogical disparities rooted in unequal teacher digital preparedness, and sociocultural differences in digital capital. These structural factors collectively shape students' access, skills, and usage patterns.

The theoretical framework was advanced by scholars such as Van Dijk [3] and Hargittai [5], who expanded the discourse beyond mere access to encompass broader issues. Hargittai's work on the "second-level digital divide" demonstrated that even

with equal access, individuals differ significantly in their digital skills and their ability to effectively and critically navigate online information. These skills are cultivated through social context, education, and cultural capital [5]. The "third-level divide" refers to the tangible benefits derived from Internet use, including improved job prospects and social mobility [3].

In educational research, a positive association among home computer access, broadband availability, and student grades is well documented [6]. A more critical perspective, termed "digital divide 2.0," cautions that pedagogically unsound technology use can itself widen achievement gaps [7]. For instance, students from higher socioeconomic backgrounds often use technology to develop skills. In contrast, their less advantaged peers may use it primarily for entertainment, a pattern influenced by the home "media ecology" [8].

The COVID-19 pandemic served as a catalyst, providing natural experiment conditions that demonstrated how the digital divide translates into learning loss. Studies globally reported significant declines in learning outcomes, disproportionately affecting low-income and rural students who lacked adequate devices, connectivity, and supportive learning environments [2, 9]. This body of work confirms the digital divide as a critical mediator of educational inequality. Yet, a synthesized model linking its structural roots to its long-term effects is still required.

### 3. METHODOLOGY

#### A. Research Design

This study employs an explanatory sequential mixed-methods design. The research proceeds in two distinct, integrated phases. First, a quantitative analysis of large-scale PISA 2018 data establishes the statistical relationship between digital access and academic achievement. Second, a qualitative thematic synthesis of recent case studies is conducted to explain the mechanisms and contexts behind the quantitative results. This design allows the qualitative findings to elaborate on and provide deeper meaning to the initial quantitative patterns, creating a comprehensive understanding of the structural digital divide.

This study employs a sequential mixed-methods design to provide a comprehensive, triangulated analysis of the structural digital divide and its educational consequences. This approach is justified by the need to address the multi-level

nature of the research problem. The quantitative phase utilizes large-scale, cross-national data from PISA 2018 to establish generalizable, statistically significant relationships between digital access and academic achievement (addressing Research Questions 1 and 2 regarding determinants and contribution to underachievement at a macro level). This phase identifies *what* the patterns are and their measurable scale.

However, quantitative data alone cannot elucidate how and why the underlying mechanisms, contextual factors, and lived experiences that constitute the "structure" of the divide. Therefore, the subsequent qualitative **phase** involves a thematic synthesis of recent case studies. This phase is designed to uncover the specific socio-technical processes, pedagogical practices, and capital disparities (Research Question 1) that explain *how* the statistical relationships manifest in real educational settings and *how* they lead to long-term consequences (Research Question 3). The integration of these two strands allows for a more plausible and robust explanation: the quantitative results demonstrate the existence and strength of the divide's impact, while the qualitative findings provide the necessary causal logic and depth to explain that impact, thereby fully justifying the chosen analytical path.

#### B. Quantitative Analysis

Data Source: Secondary data were obtained from the 2018 Program for International Student Assessment (PISA) dataset, which includes over 600,000 students from 79 countries and economies. The 2018 cycle provides a robust pre-pandemic baseline.

- **Dependent Variables:** Standardized test scores in mathematics, reading, and science.
- **Independent Variables:** A composite "Digital Access Index" (DAI) was constructed from student responses regarding: availability of a dedicated computer for schoolwork, quality of internet connection, and access to educational software at home (Cronbach's  $\alpha = 0.79$ ).
- **Control Variables:** PISA index of Economic, Social, and Cultural Status (ESCS), school location (urban/rural), and gender.

**Analytical Approach:** A multiple linear regression analysis was conducted to examine the relationship between the DAI and academic performance, controlling for socioeconomic and demographic factors. Analysis was performed using SPSS v.28.

Descriptive statistics for key variables are presented in Table 1

Table 1: Descriptive Statistics Of Key Variables (N ≈ 600,000)

Variable	Mean	Standard Deviation	Min	Max
Mathematics Score	489.2	93.5	262.4	787.7
Reading Score	486.8	96.2	247.3	792.0
Science Score	488.9	94.1	258.9	785.8
Digital Access Index (DAI)	0.00	1.00	-2.34	1.98
ESCS Index	0.00	1.00	-4.28	3.41

C. Quantitative Analysis

Data Source: A systematic review of 25 peer-reviewed case studies published between 2019 and 2024 was conducted, selected from Scopus-indexed journals.

Analytical Approach: A thematic analysis was conducted using the process outlined by Clarke and Braun [10], which involved familiarization, code generation, theme identification, review, and definition.

4. RESULT AND ANALYSIS

A. Quantitative findings

The regression analysis revealed a statistically significant positive relationship between the Digital Access Index (DAI) and academic performance in all three domains after controlling for ESCS, location, and gender (p < 0.01). As detailed in Table 2, a one-standard-deviation increase in the DAI was associated with a significant increase in scores across all subjects.

Table 2: Multiple Regression Analysis Predicting Academic Scores (Standardized Coefficients B)

Predictor Variable	Mathematics	Reading	Science
Digital Access Index (DAI)	0.11	0.14	0.10
ESCS Index	0.28	0.30	0.27
School Location (Urban=1)	0.05	0.04	0.05
Gender (Female=1)	-0.01	0.12	-0.02
R <sup>2</sup>	0.29	0.31	0.28

Crucially, the effect of digital access remained significant even when controlling for socioeconomic status, though the ESCS was a stronger predictor. This suggests that while digital

access is closely tied to general socioeconomic advantages, it also has an independent impact on academic outcomes. Interaction effects revealed that the impact of the DAI was more pronounced for students from lower ESCS backgrounds, suggesting that the lack of access compounds existing disadvantages.

B. Qualitative Thematic Analysis: Structural Determinants

The thematic analysis identified three overarching structural determinants that drive the digital divide and its educational impact, as synthesized in Figure 1.

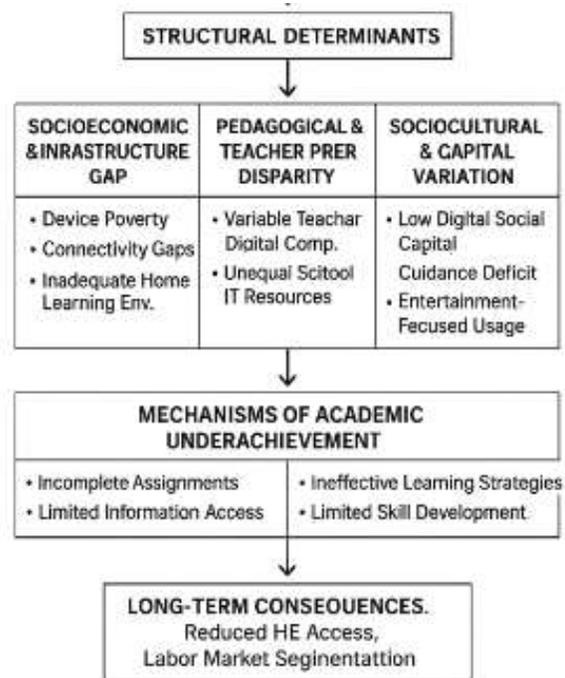


Figure 1: Conceptual Framework of Structural Determinants and Impacts of the Educational Digital Divide

- The Socioeconomic and Infrastructure Determinant: This primary barrier is characterized by a trifecta of challenges: (a) Device Poverty: A lack of functional, up-to-date computers for exclusive educational use, forcing reliance on smartphones ill-suited for complex tasks [11]. (b) Connectivity Gaps: Unreliable, slow, or unaffordable broadband internet, with students sometimes traveling to public Wi-Fi spots [9]. (c) The Home Environment: A lack of quiet, dedicated study space, compounded by device-sharing among multiple siblings.
- The Pedagogical and Teacher Preparedness Determinant: This "second-order" divide

exists within schools. Studies reveal [7, 12]: (a) Variability in Teacher Digital Competence: Teachers in better-resourced schools more frequently use technology for creative tasks, whereas those in under-resourced schools often default to drill-and-practice exercises. (b) School-Level Resource Allocation: Disparities in IT infrastructure, technical support, and digital platform availability create unequal learning experiences within the same educational systems.

3. The Sociocultural and Capital Determinant: This theme relates to intangible resources shaping technology use. Students from families with high "digital social capital," where parents possess the skills to guide online learning, navigate educational technology more effectively [5]. Conversely, students from low-digital-capital households often lack guidance, leading to less productive, entertainment-focused usage that reinforces the skills gap [8].

## 5. DISCUSSION

The findings demonstrate that the digital divide functions as a powerful vector of academic underachievement. Its effects, however, extend far beyond immediate test scores, casting a long shadow over future life trajectories and social mobility.

These structural determinants contribute to academic underachievement by restricting access to digital learning resources, hindering the development of digital literacy, weakening engagement and self-regulated learning, and amplifying learning loss during periods of remote or hybrid instruction.

1. Constriction of Higher Education and Skill Development Pathways: Academic underachievement linked to digital disadvantages directly limits tertiary education options. The university application process itself, researching programs, completing online forms, and submitting digital portfolios, is heavily digitized, creating a significant barrier [13]. Furthermore, an inability to develop advanced digital literacy in secondary school leaves students unprepared for STEM fields and other digitally intensive university programs, effectively closing off high-growth career paths.
2. Labor Market Segmentation and Economic Precarity: The modern labor market is increasingly polarized into high-skill, high-

wage jobs requiring digital fluency and low-skill, low-wage jobs that do not [14]. Students who exit the educational system on the wrong side of the digital divide are funneled into the latter category, facing higher risks of unemployment and underemployment in economies driven by automation. This risk creates a "digital underclass" with limited economic mobility.

3. The Perpetuation of Intergenerational Inequality: The consequences are cyclical. Adults who suffer economic precarity due to digital exclusion are less able to provide the devices, connectivity, and digital social capital for their own children. This recreates and reinforces the very structural determinants that initiated the cycle, thereby entrenching digital inequality across generations [3].

The COVID-19 pandemic catalyzed research, providing natural-experiment conditions that unequivocally demonstrated how the digital divide translates into learning loss. Studies from around the world have reported significant declines in learning outcomes, disproportionately affecting low-income and rural students who lacked access to devices, connectivity, and supportive learning environments at home [2, 9].

This finding is supported by research in the Jordanian context, where a study concluded that "infrastructural obstacles significantly hampered the success of e-learning. The most prominent challenges were the lack of a stable internet connection and the high cost of data packages, which created a substantial barrier for a considerable portion of the student population" [15]. This body of work confirms the digital divide as a critical mediator of educational inequality.

### A. Policy Implications

Addressing this challenge requires multi-pronged, systemic interventions that target each determinant illustrated in Figure 1:

The long-term socioeconomic consequences include reduced opportunities for higher education, exclusion from digitally intensive labor markets, increased risk of unemployment, and the intergenerational reproduction of digital and socioeconomic inequality.

- Infrastructure as a Public Utility: Policy must treat broadband internet as an essential utility, investing in infrastructure in underserved areas and subsidizing access for low-income families.
- Holistic Digital Literacy Programs: Educational

initiatives must foster critical digital literacy, including information evaluation and digital citizenship, integrated across the curriculum for all students.

- Empowering Educators: Investment in continuous, high-quality professional development is crucial to ensure teachers can leverage technology for innovative and equitable pedagogy.
- Community-Based Support: Establishing community technology centers and providing digital skills training for parents can help bridge the sociocultural capital gap.

## 6. CONCLUSION

This study demonstrates that the digital divide functions as a fundamental structural force shaping academic performance and long-term educational trajectories. By integrating quantitative analysis of PISA 2018 data with qualitative thematic evidence, the research illustrates how infrastructural disparities, uneven pedagogical preparedness, and variations in sociocultural and digital capital interact to produce systematic educational disadvantages. The quantitative findings confirm that digital access exerts a significant and independent influence on core academic competencies. At the same time, the qualitative analysis highlights the layered mechanisms through which exclusion unfolds in practice.

Importantly, this study contributes a multi-dimensional framework that links structural determinants of digital exclusion to both immediate academic outcomes and broader socioeconomic inequalities. The long-term implications of restricted pathways to higher education, segmented labor market participation, and the intergenerational reproduction of disadvantage pose a significant challenge to social mobility and national human capital development. Addressing these inequalities requires coordinated, evidence-based interventions, including targeted infrastructure expansion, sustained investment in teacher digital capacity, and the integration of equitable digital literacy programs into school curricula.

While this study provides an integrated analysis of the digital divide's structural causes, several limitations and avenues for future research remain apparent.

First, as noted, our quantitative analysis relies on cross-sectional data (PISA 2018), which constrains our ability to make definitive causal claims or

model how digital exclusion *accumulates* over a student's educational trajectory. This points to a significant methodological gap: the need for longitudinal, cohort-based studies that track students' digital access, skill development, and academic outcomes over time to better model the compounding nature of digital disadvantage.

Second, while our mixed-methods approach identifies key structural determinants, the relative weight and interaction of these factors (e.g., how teacher preparedness moderates the effect of infrastructural lack in specific contexts) require more granular investigation. Future research should employ multi-level modeling and comparative case studies to disentangle these complex interactions and identify the most critical leverage points for intervention in different socioeconomic or geographical settings.

Third, our study and much of the literature focus on divides in *access* and *basic use*. A critical emerging gap is the "fourth-level divide": inequities in the ability to use digital tools for creation, innovation, and computational thinking—skills paramount for the future labor market. Research is needed to understand how educational policies and curricula can proactively prevent this next-stage stratification.

Finally, there is a pressing gap in rigorous policy evaluation. As governments and institutions implement interventions (e.g., device distribution, teacher training), robust studies are needed to measure their effectiveness in not only improving access but also in closing outcome gaps and disrupting the intergenerational cycle of digital inequality highlighted in our discussion.

Future research should investigate how these themes interact in localized settings, how they influence emerging 'fourth-level' outcome divides, and how targeted interventions might disrupt their compounding effects.

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