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Article

The Impact of Accessing Education via Smartphone Technology on Education Disparity—A Sustainable Education Perspective

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Abstract: Following the fourth target of the United Nations' Sustainable Development Goals (SDGs), education disparity is one of the graver concerns delaying substantial economic development, especially in emerging market-based nations. Despite numerous efforts to address this disparity, it has been a long-standing concern for many communities. It is important to note that the recent pandemic has changed teaching and learning approaches worldwide, where disparity is one of the most challenging issues. Although similar and/or equal access to technology has always been challenging, online learning practices were widely implemented with varying levels of success during the pandemic. Using purposive sampling on administrative data between 2020 and 2022 on undergraduate programs in public universities in Bangladesh, this study examines the effects of technology access on academic achievement. This study employs the difference in differences (DID) technique to analyze the data and finds that access to technology improves students' learning. Findings strongly suggest that technology access reduces disparity, mainly due to socioeconomic status (SES). Findings also imply that ensuring access to technology for individuals from poorer SES backgrounds should be prioritized to address education inequality-related challenges.

Keywords: smartphone technology; education disparity; sustainable education; pandemic; academic performance

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1. Introduction

Technology has become one of the most influential drivers of economic growth and development [1–3]. In particular, the internet has accelerated the spread of knowledge and how information is transmitted. In addition, it allows networking that leads to knowledge spillovers between individuals, firms, industries, regions, and countries [4], thus contributing to economic growth or expansion [5]. From a theoretical perspective, the diffusion theory of Rogers [6] highlights the role played by education innovation and its dissemination. However, empirical evidence has also confirmed that the effects of technology on economic growth depend on how these technologies and skills are deployed. In particular, more educated individuals use computers and access the internet more frequently [7], leading to economic prosperity [8].

The coronavirus has recently transformed many aspects of human lives, forcing individuals to stay home and shut down schools, businesses, and workplaces. Technology has also played a significant role in overcoming these challenges [9]. For example, as the schools moved online, learners experienced profound changes. Approximately 93% of parents with K–12 children in the United States argue that their children had some online instruction during the pandemic (https://www.pewresearch.org/internet/2021/09/01/the-internet-and-the-pandemic/, accessed on 10 February 2023). However, many in developing countries fell behind academically and required technical and language skills for internet usage [10]. In addition, socioeconomic status does play an essential role in shaping learning attainment and subsequent professional careers. For example, socioeconomic inequalities may affect access to information and knowledge associated with technology use. To address these issues, digital inclusion allows individuals to obtain the most recent information promptly and thereby achieve their ultimate objectives, provided that they have consistent access to such digital technologies. This study examines how technological inclusion affects academic achievement despite the financial inequalities that mark student cohorts throughout the world.

From a theoretical perspective, there are a few channels through which technology use may affect education outcomes. For example, individuals could have their own strengths and weaknesses when learning various topics. Internet access has the potential to offer these individual-specific instructions or education materials, which may not be achieved in group instruction scenarios [11]. The internet is also a valuable resource for information on various topics. These advantages could reduce the coordination costs of group projects. Cuban [12] argues that computers, the internet, software, and other technologies offer interactive platforms to engage learners even without their physical presence altogether. Other studies, such as Todd et al. [13], argue that computer-related resources can be added to a standard model for education-related purposes. However, the constraints in such models are the financial ability and skills required to use these resources.

The irruption and diffusion of digital technologies can also facilitate learning achievement. The use of technological tools in the production process leads to education and training systems offering new opportunities to integrate pedagogical resources [14], improve communication between teachers and students [15,16], offer more flexibility across the learning process [17], and reinforce the interaction between different educational resources [18–20]. With this in mind, many studies empirically investigate the impact of technology use on desired outcomes. Angrist and Lavy [21] pointed out that computers can mainly be used in the education sector in two ways. Firstly, computer skills training teaches students how to use computers, and secondly, computer-aided instruction uses computers to teach topics that may or may not have any relationship to technology. Scherer [22], Goolsbee, and Guryan [23] find that using the computer is less effective than conventional instructional methods. In contrast, Castillo-Merino et al. [24], Fuchs and Woessmann [25], and Noll [26] argue that there is a positive relationship between information and technological development in education. Nonetheless, technology use may also correlate with other unobserved or imperfectly measured education inputs. Azevedo et al. [27], Hanushek et al. [28], and Hanushek and Wößmann [29] argue how technology through investment in schools affects outcomes. Using randomized control trials, other studies [30–32] found limited but positive effects of technology use on learning attainment.

As studies argue that technology use boosts students' grades and how they learn, students with poorer parents could struggle compared to their higher-income counterparts. For example, Fuchs and Fuchs [33] and Asongu and Odhiambo [34] show empirical evidence for a relationship between Information and Communication Technologies (ICT) and income inequality. Furthermore, most studies showing the effects of education inequality on economic growth do not consider the impact of the technology used in their models [35–37]. A limited number of studies, such as Billon et al. [38], Wahiba et al. [39], and Nga Ndjobo et al. [40], examine the relationship between education inequalities and technological usage. In this study, we first examine the impact of technology access on academic achievement. We then examine whether technological access reduces the disparity in attainment.

Considering Bangladesh during the pandemic as a case study, this study examined the above hypotheses. On 20 March 2020, the government postponed conventional physical-academic activities because of the COVID-19 pandemic. Consequently, most universities commenced online classes, which also required electronic devices. However, this appeared to be or was very costly for some students and was not affordable. As a result, many students from remote areas could not regularly attend or even start online academic activities. Therefore, the government offered financial incentives for using smartphones to conduct online classes as a solution. Based on this, the present study considered the smartphone program an intervention.

In this technology-driven era, knowledge and information transmission can help implement and achieve the Sustainable Development Goals (SDGs). The United Nations (UN) also emphasizes societies where everyone can learn and communicate through access to ICTs. On the other hand, sustainable learning refers to educational approaches that contribute to a healthy, ever-changing learning environment by generating and sharing knowledge in a community. Technology access offers opportunities to explore knowledge and remove the glaring disparities in academic attainment, ultimately ensuring sustainable and viable education where all people benefit.

This study conducted randomized natural experiments and found that technological use reduces disparities in academic achievements among students. This study contributes to the literature in the following ways: Firstly, using panel data and difference in difference (DID) methodology, this study argued that technology increases students' academic attainment by 0.12. The approach removes biases between the treatment and control groups of students, which could result in permanent differences. It also eliminates biases from comparisons over time in the treatment group that could result from other specific causes. Secondly, this study found that technology reduces the inequality in academic attainment between students from higher and lower socioeconomic groups. This finding is significant because education inequality is closely associated with skill deficiencies in adulthood [41,42]. Higher income inequality would lead to sensitive equality issues of opportunity and intergenerational mobility. Connolly et al. [43] recognize that the link between parental income and children's prospects increases once the latter have become adults. This finding suggests that technological inclusion reduces the gaps between education success for students from higher and lower socioeconomic groups, which ultimately would help make adulthood more equitable regarding access to employment opportunities.

2. Literature Review

This section first defines the development concept and its link to the SDGs. Then it describes sustainable education and finally discusses how education disparity undermines the goal of sustainable education, with a particular emphasis on the role of technology in education disparity.

2.1. Concept of Development and SDGs

The relevant development criteria and schemata have evolved from historical and social practices [44]. The interpretation of social events is guided and constrained by prevailing rationales and assumptions that reflect the dominant ideology and how it is articulated in politics, economics, and social discourse [45]. For instance, Alam et al. [46] noted that natural resources were considered the single source that triggers development. They further argued that to exploit such an ideology, innovation of an "abstract concept", namely money, was revolutionized, gradually coming to dominate the concept of economic development when profits became a goal in itself [47]. As time passed, the concept of natural resources as a primary or single source for development became obsolete since human resources are now regarded as a fundamental part of economic development. Hence, Vom Hau et al. [48] and Alam et al. [49] argued that human resources could transform both useable and non-useable natural resources for the benefit of humanity, which is what development should be about. However, Cozier [50] and Lozano et al. [51] claimed that development simply became a core aspect of international business and was at the mercy of modernization and commodification.

Alam [52] argued that the concept of development had been experimented with in many paradigm transformations and could contradict the former explanation with the latter. Contemporary development, as it is now practiced, may threaten future definitions [41]. Economic development (i.e., capitalism) was considered the only form of progress for much of the nineteenth and twentieth centuries, as was modernization. Consequently, significant amounts of human resources were invested in ensuring that capitalist methods of production and ownership were maintained, subsequently leading to commodification [49].

It was later realized that such activities would have damaged our environment and natural sustainability if they went ahead unchallenged [46]. Moreover, this led to a belief in a sustainability crisis consciousness, where the new paradigm is branded sustainable development. To respond to this transition, the United Nations (UN) reworked the targets of the developmental agenda identified as SDGs (Sustainable Development Goals) in 2015. Since then, the concept of sustainable development has been considered an emerging and popular theme worldwide.

2.2. SDGs: Sustainable Education

While the key focus of the SDGs is to ensure environmental and natural sustainability with the collective efforts made to realize the seventeen targets, each target has its own distinct purpose [53]. These seventeen targets function collectively to ensure sustainable development [54,55]. Hence, sustainable education is essential to targeting the fourth SDG, which is entirely different from sustainability in education [56]. However, scholars could disagree on how to define 'sustainability in education' and 'sustainable education', as they may be entirely or subtly different.

Sustainability in education refers to agendas, programs, studies, and institutional infrastructure development connected to the environment and nature [57,58]. On the other hand, sustainable education refers to those developmental agendas that confirm that education can play a substantial role in economic and social progress and focus on a human needs perspective [59,60]. Therefore, the true meaning of sustainable education goes beyond the desired quality of education; instead, it is more of a comprehensive tool. Furthermore, sustainable education includes programs, agendas, and institutional settings that work in the interest of national development and in an unbiased way [52].

2.3. Education Disparity and Sustainable Education: The Era of Technologization

The disparity in education has a long history [61,62]. Many attempts have been made to address such disparities in education, yet it remains a core challenge for sustainable development in education. Despite adopting the ratification named "Convention against Discrimination in Education 1960" [52] for several reasons, such efforts were not successful for many developing nations. One of the common constraints based on several nations' experiences suggests that if a nation experiences disparity in every aspect of its society, politics, economy, community, etc., then removing education disparity is impossible [63]. For this reason, the SDGs concentrate on addressing education disparity and use a combined process to remove it from the social setting [52]. Subsequently, several SDG targets, namely one, two, five, eight, and ten, contribute to a collective and collaborative effort to remove the education disparity evident in the fourth SDG.

Although addressing education disparity remains the top priority, it is still one of the most severe concerns affecting the future of sustainable development in education [64]. While disparity is a problem, technology has become essential to our daily lives in the 21st century. Education, a social and economic reform instrument, cannot live in isolation from technology [65]. Binks et al. [66] argued that technology had become an inevitable component of the preparation of courses and curricula, extending to the delivery of curricula and grading/marking/assessments. Hence, not only is equal access to education a remedy for education disparity, but substantial equal access to technology has become one of the foremost prerequisites for dismantling education discrimination [67,68]. Therefore, the role of technological intervention in education disparity is important to investigate in the era of technologization and sustainable development.

3. Context of This Study

On 20 March 2020, classroom-based academic activities in Bangladesh were postponed due to the spread of the lethal COVID-19 pandemic throughout the school system. Consequently, the authorities launched online classes in April 2020. There were more than 304,414 students at 46 public universities nationwide at that time. Most universities started online classes because there was no indication of when the coronavirus would end. Moreover, students from higher socioeconomic backgrounds could continue their classes because they had electronic devices. In contrast, many students from remote areas could not afford to do academic activities online because they were too poor to afford such devices. For example, approximately 55% of students do not have online educational devices. Even among those who have, about 43% have to watch TV educational programs, which are the main form of remote learning while schools are closed (https://www.worldbank.org/en/results/2021/04/18/keeping-bangladesh-s-students-learning-during-the-covid-19-pandemic, accessed on 11 January 2023).

Moreover, many public university students reportedly did not have smartphones, depriving them of virtual class participation. Currently, the cost of monthly internet packages is reportedly not feasible for low-income students. Assessing realities on the ground, the University Grants Commission (UGC) of Bangladesh took the initiative to provide financial support, i.e., Bangladeshi Taka (BTD) 8000, equivalent to USD 93 in 2021, for purchasing smartphones. Only students without a smartphone could receive this kind of support. This provision is considered an interest-free soft loan to be repaid in installments. The UGC will disburse the money to students through their respective universities.

Approximately 21% of the total students at the university in Netrokona applied for such a soft loan. They constituted the highest percentage throughout the country, while one university in Khulna had the lowest at 3.36%. A significant share of students at the other largest universities also applied for the loan. For example, 19.89% of the total 43,000 students at Dhaka University applied for such financial assistance. In comparison, it is 19.18% of the 7500 students at Bangladesh University of Engineering and Technology, 17.80% of the 12,921 students at Jahangirnagar University, 15.63% of the 19,230 students at Jagannath University, 15% of the 25,000 at Chittagong University, and 12.40% of the total 38,257 students at Rajshahi University.

4. Data and Model

This study considered a public university in Bangladesh and employed a quantitative model, namely difference in differences, to examine the impact of technology access on academic achievement.

4.1. Data and Samples

We collected administrative data from one of the largest public universities, whose name remains confidential. This university is academically solid and well-reputed, with newly admitted students having an average high school cumulative grade point average (CGPA) of 3.51 on a scale of 4.00. Students at this university usually live in residence halls from their second year on. Specifically, the four largest departments were chosen because they have, on average, 50 undergraduate students. We randomly selected 25 students in each department who had accepted the government-provided smartphone and the remaining 25 who did not have a smartphone. In other words, the treatment groups are those students who receive the smartphones, and those who do not receive them are the control groups. Therefore, the total sample for the control group is 100, while there are 100 in the treatment group. The specific departments were Civil Engineering, Computer Science and Engineering, Electrical and Electronic Engineering, and Mechanical Engineering. More than 90% of students live in residential halls, while the remaining live closer to the schools, with a maximum 10-min walk.

In addition, we considered students who completed at least two semesters before the pandemic's detection in 2020. The reason for this is that the pandemic was officially detected in February 2020. These constitute the pre-intervention data, and as the Bangladesh government imposed a lockdown in March 2020 and allowed online classes with many other strategies, we used administrative data on these students in 2021 and onwards. These were the post-intervention data. As the smartphone program was initiated in 2020, we did not use any data for that year. Therefore, we have four-semester academic achievements for each student: two are earlier than the intervention, and two are post-intervention. In addition, using a structured questionnaire, we surveyed these students about their technological skills, study duration, and internet speeds each semester.

4.2. Empirical Model for Randomized Natural Experiments

To identify the effects of technology on academic outcomes, we employed a quasi-natural experiment. For example, the Bangladesh government provided a soft loan to buy technology to be used for online educational purposes. The variations in difference in difference (DID) estimation mainly come from intervention, making it possible to compare the difference in academic achievements between beneficiaries and non-beneficiaries before and after the program. To examine the treatment effect, we specify the DID estimation as follows:

$$y_{it} = \alpha_0 + \alpha_1 time_{it} + \alpha_2 treat_{it} + \delta treat_{it} * time_{it} + X'_{it}\beta + d_i + \lambda_t + e_i, \quad (1)$$

where, y_{it} is the CGPA of student i in t semester; $treat_{it}$ is a binary indicator for receiving a government smartphone, otherwise 0; $time_{it}$ denotes the binary indicator after the student i receives the smartphone in t semester, otherwise 0; X'_{it} stands for the vector for control variables, such as financial capital, digital literacy, and experience in the same business.

The symbol d_i represents the district-fixed effects, controlling for the time-invariant characteristics of different cities, such as geographic factors. Meanwhile, λ_t denotes the COVID-19 fixed effects to capture the factors that affect the academic outcome in a given year. The outcome variable is the CGPA. The coefficient of interest, δ is the DID estimator, represents the impacts of smartphones on academic outcomes. The DID estimate is expected to be positive and statistically significant, indicating that smartphone intervention effectively improves education outcomes. The symbol β is the estimated effects of the covariates on academic attainment, and e_i is the error terms. Using the Event Study design, Figure A1 in Appendix A satisfies the parallel trends assumption.

5. Results and Discussion

5.1. Descriptive Statistics

Table 1 summarizes the statistics of the variables. Following standard literature on the economics of education, we used the CGPA to measure academic achievement quantitatively. The average CGPA of the whole sample is 3.12, while it is 2.94 for the control group and 3.30 for the treatment group. Likewise, the average family income, measured in Bangladeshi Taka (BTD) thousands, of the entire sample is 39.69, which is similar for both groups. A higher standard deviation of the average income represents a higher variation in family earnings.

Table 1. Descriptive Statistics.

	Full Sample		*Control Group*		*Treatment Group*	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**	**Mean**	**Standard Deviation**
CGPA	3.1219	0.4160	2.9412	0.3610	3.3025	0.3883
Family income	39.6904	35.0113	39.8795	35.0334	39.5014	35.0320
Self-tech use hours	2.1782	0.5993	2.1055	0.5372	2.2509	0.6481
Family tech use hours	3.6969	1.7938	3.3455	1.4436	4.0484	2.0278
Internet speed	3.0344	1.0311	3.0064	0.9973	3.0623	1.0644
SES index	4.1425	2.3779	4.1625	2.3812	4.1225	2.3773
Tech skills	5.1950	2.5525	5.1450	3.2704	5.2450	1.5316

Table 1 also shows the average technology use in hours for education purposes. For example, on average, 2.18 h are spent for the whole sample, while 2.11 and 2.25 h are spent for the control and treatment groups, respectively. On average, the students' family members in the control group spent 3.35 h, compared to 4.01 h for the treatment group. We considered family income and the education status index to quantify the socioeconomic (SES) indicator. Firstly, family education attainment and income are classified into five categories. The highest category is denoted by an indicator value of 5.00; consequently, the lowest value is 1.00. The average of these two values is used to measure the SES of students. The average index for the SES is 4.14 for the whole sample, while it is 4.16 and 4.12 for the control and treatment groups, respectively. Technological skills could also play a significant role in online instruction. We employed a scale of ten for the excellent skills and consequently one for the poorest skills. The average skills for the whole sample are 5.20, while they are 5.15 and 5.25 for the control and treatment groups, respectively. These statistics indicate that treatment and control group students have moderate technology skills.

Figure 1 displays the average outcome variables for the control and treatment groups. The average CGPA is 2.91 for the control group before the intervention and 2.97 after the intervention. The average values of the treatment groups are 2.96 and 3.65, respectively. The average CGPA difference between the treatment and control groups in the pre-intervention period was 0.05. Using the t-significance test, this difference is not statistically significant, indicating that the treatment and control groups were likely to be similar before the program intervention commenced. On the other hand, the post-intervention difference between the treatment and control groups is 0.68 and is statistically significant. These results strongly suggest that the smartphone intervention program could significantly influence academic outcomes.

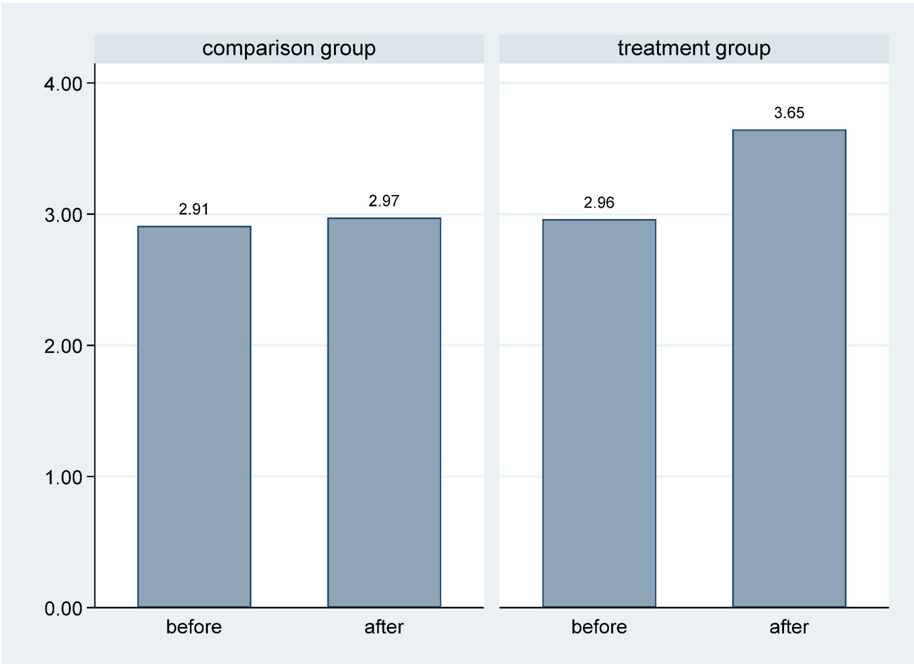

Figure 1. Comparison between the average CGPAs between the treatment and control groups.

One advantage of using this panel data is that there are multiple periods. Another advantage is that this official information will likely have fewer measurement errors than survey data. However, one drawback of using this data set is that family earnings are not fully observed. While there would be a particular concern if CGPA or family earnings were endogenous to other variables, individual-specific effects could control this effect.

5.2. Estimated Impacts of Access to Technology

The results of this study are presented below in two sub-sections. Firstly, we explore the relationship between technology use and education performance before determining the effect of technology on addressing the disparity.

5.3. Use of Technology and Performance

Table 2 tabulates the treatment effect of the smartphone on academic attainment. Column 1 reveals that the estimated impact of the smartphone is 0.36, and it is significant. This model in Column 1 does not consider any control variables or other fixed effects. A positive and significant impact means that smartphones significantly improve students' learning outcomes. Students with smartphones receive higher grades than their counterparts by 0.36. Other factors could also affect educational success. Column 2 incorporates family income into the same model.

Table 2. The estimated effects of mobile phones on academic achievement from the DID model.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
treatment	0.3613 ***	0.3610 ***	0.4287 **	0.4144 ***	0.4114 ***	0.3490 ***	0.3484 ***	0.3194 ***	0.3414 ***
	(0.0371)	(0.0372)	(0.2180)	(0.1085)	(0.1086)	(0.0871)	(0.0872)	(0.0840)	(0.0772)
Income		−0.0008 **	−0.0012 ***	0.0006 ***	0.0002	0.0003	0.0003	0.0004	0.0003
		(0.0004)	(0.0004)	(0.0002)	(0.0005)	(0.0004)	(0.0004)	(0.0004)	(0.0003)
				(0.0154)	(0.0154)	(0.0161)	(0.0165)	(0.0163)	(0.0156)
SES index					0.0060	0.0012	0.0012	0.0003	−0.0017
					(0.0063)	(0.0051)	(0.0051)	(0.0048)	(0.0044)
Self-tech use hours						0.2682 ***	0.2680 ***	0.1542 ***	0.0069
						(0.0147)	(0.0147)	(0.0200)	(0.0231)
Tech Skill							0.0001	0.0002	0.0000
							(0.0002)	(0.0002)	(0.0002)
Family tech use hours								0.0513 ***	0.0705 ***
								(0.0064)	(0.0061)
Search numbers								0.0045	0.0238 ***
								(0.0085)	(0.0080)
Internet speed									0.1144 ***
									(0.0109)
Individual FE			Yes	Yes	Yes	Yes	Yes	Yes	Yes
Semester FE				Yes	Yes	Yes	Yes	Yes	Yes
Constant	2.9412 ***	2.9750 ***	2.9578 ***	2.6315 ***	2.6208 ***	2.1629 ***	2.1609 ***	2.2343 ***	2.0692 ***
	(0.0262)	(0.0302)	(0.1547)	(0.0776)	(0.0784)	(0.0677)	(0.0682)	(0.0827)	(0.0776)
N	800	800	800	800	800	800	800	800	800

Note. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively. The robust standard error is clustered at the department level.

The size of income indicates that students from families with a higher income could also achieve higher grades. The estimated effect of the treatment is also significant, meaning that smartphones increase students' academic attainments. The abilities of individual students could be different from others. Therefore, individual ability could also affect what they attain and how they go about their learning. Similarly, students take various courses with different instructors from semester to semester. We controlled individual fixed and semester fixed effects to capture these fixed effects. Column 3 and onwards report the estimated results with these fixed effects. For example, Column 4 documents the estimated impact of treatment by controlling individual fixed effects. The positive and significant results suggest that smartphones increase students' academic success.

5.4. Technological Inclusion: Effect on Education Disparity

We chose students from similar geographical areas to determine whether technological inclusion diminishes the education disparity between students from higher- or lower-income families. The district is considered an indicator of the same geographical areas. The 36 pairs of students in the control group came from a similar location, as did the 29 pairs in the treatment group. The family income differences for each student pair are considered to be definitive socioeconomic status differences. The remaining students in both groups are excluded from this estimation procedure.

We assume that the differences in CGPAs for the pair of students are a proxy for the education disparity. To confirm whether socioeconomic differences affect the disparity in what students achieve, we used a pooled ordinary least squares (POLS) model. The findings imply that the effects of the socioeconomic difference are positive and statistically significant. For example, Columns 7 and 8 in Table 2 report that the family technology use index positively helps academic achievement. In other words, for students with family members who use more technology daily, their learning is improved. This significant outcome motivates us to examine whether SES increases disparities in academic achievement.

To examine whether technological inclusion affects academic disparity, we employed the following model:

$$y_{jt} = \alpha_0 + \alpha_1 treat_{jt} + X'_{jt}\beta + d_j + \lambda_t + e_j,$$

where, y_{jt} is the CGPA differences of j pair of students i in t semester; $treat_{jt}$ a binary indicator for receiving a government smartphone, otherwise 0; and X'_{jt} denotes the vector for differences in control variables. The coefficient of interest, α_1, is the DID estimator, representing the impacts of smartphones on business outcomes. The DID estimate is expected to be negative, indicating that smartphone intervention effectively curtails education disparity in CGPAs.

Table 3 shows the impact of the smartphone on diverging levels of academic attainment. Column 1 displays that the estimated effect is negative and statistically significant. This means that smartphones reduce educational achievement differences between higher and lower socioeconomic students. We also control the individual and semester fixed effects by incorporating more variables into the model, but we still find the estimated treatment effect to be negative and significant. These findings imply that technology access can reduce academic disparity. There could be many channels for such achievement. For example, technology can offer students access to digital resources, including e-books, online courses, and educational resources that can help them learn more effectively. Second, the smartphone gives students access to online tutoring services to improve their academic performance. Third, technology can help teachers provide students with specific instruction, followed by individual learning needs and preferences. Finally, students can use smartphones to facilitate collaborative learning by working together on assignments and other academic activities, regardless of location.

While this study argues that technology greatly assists academic attainment, prior literature has reported mixed findings. For example, Mendoza et al. [69], Giunchiglia et al. [70], and Pérez-Juárez et al. [71] argued that excessive smartphone use could be a source of distraction, adversely affecting learning. Other studies, such as Gökçearslan et al. [72] and Montag and Elhai [73], argue that students who are permitted to keep their smartphones in the classroom are continuously distracted by text messages and other non-academic issues. In addition, students looking at their smartphones during classroom time have shorter attention spans. On the other hand, research such as that by Higgins et al. [74] and Alsalhi et al. [75] argues that technology use is positive for academic attainment. For example, mobile devices do not cause technostress for students; instead, they help improve their academic performance [76]. Our findings are consistent with the later stream of literature.

As education can play a crucial role in achieving the SDGs, reducing educational disparity can also accelerate such a process. For example, when people obtain quality education, they can lift themselves out of poverty. Higher academic achievement also helps empower people everywhere and allows them to live healthier and more sustainable lives. Our findings suggest policymakers ensure equal technology access for everyone with adequate training. This implication is eventually similar to goal four of the SDGs, ensuring inclusive and equitable quality education.

Table 3. Impact of the Smartphone on the difference in academic attainment.

	(1)	(2)	(3)	(4)	(5)	(6)
Treatment	−0.1212 ***	−0.1101 **	−0.1004 ***	−0.1231 ***	−0.1317 ***	−0.1204 ***
	(0.0091)	(0.0012)	(0.0103)	(0.0109)	(0.0201)	(0.0109)
Self-Tech Use hours				0.1001 ***	0.1210 ***	0.1121 ***
				(0.0117)	(0.098)	(0.0112)
Tech use hours					0.0111	0.0128
					(0.0032)	(0.0042)
Family tech Use hours						0.0871 ***
						(0.0231)
Search numbers						0.0847
						(0.0901)
Individual FE		Yes	Yes	Yes	Yes	Yes
Semester FE			Yes	Yes	Yes	Yes
Constant	2.9412 ***	2.9578 ***	2.6315 ***	2.1629 ***	2.1609 ***	2.2343 ***
	(0.0262)	(0.1547)	(0.0776)	(0.0677)	(0.0682)	(0.0827)
N	260	260	260	260	260	260

Note. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively. The robust standard error is clustered at the department level.

6. Conclusions

The problem of education disparity has been a long-standing concern for many communities. Like other sectors, the recent pandemic has changed teaching and learning approaches worldwide at short notice. Although implementing equitable and equal technology access is challenging, online learning practices offer a relatively more accessible avenue to minimize the disparity in academic attainment. This study employed the difference in differences (DID) method and found that technology improves students' grades and how they learn. Findings imply that technology access reduces academic disparity despite the differences in socioeconomic backgrounds that students have. Therefore, policymakers should ensure technology access is made possible for all students and teachers, regardless of socioeconomic status, with sufficient training to address education inequality-related challenges.

This study has both theoretical and practical implications for education. Firstly, theories suggest that well-functioning education systems support national development if the human needs perspective is catered for so that people can economically and socially progress. These concepts are closely interrelated, and one cannot thrive without the other. However, the disparity remains one of the significant challenges to attaining the desired level of national development. Education is treated as an essential tool that can remove social disparities.

Secondly, the practical implication suggests that although technology supports learning outcomes, it should not be the primary tool for education as it is an outcome of education. Therefore, technology should remain a supplement that helps to improve education and learning affairs but should not dominate all the relevant processes. Equal technology access can be supplementary and complementary to ensuring sustainable education. Otherwise, technological intervention would aggravate the education disparity if only the elites in society were supported.

Although this study argues that technology access is required for sustainable education, it has the following limitations: Firstly, there could be only trickle-down effects of technological development across the country. Isolating the impacts of the smartphone intervention from such effects is beyond the scope of this study. Secondly, the rural and urban settings and internet speeds, which can vary hugely between both, could also affect online classes. For example, students in rural areas could attend online classes outside of their homes, leading to heterogeneity, while this study only examines the average impact. Thirdly, despite this study controlling these outcomes by incorporating individual fixed effects, future studies should employ more robust methods and data to isolate the technological impact more accurately. Fourthly, technology could undermine learning outcomes when students use it for non-academic purposes, such as entertainment and gaming. Future studies would examine the net effects of technology use on academic attainment. Finally, this study considers only one university for four semesters. A country-wide study or international comparison would offer more policy insights that would make it possible to understand what sustainable education means in one country compared to another.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data are identifiable and are available upon request.

Conflicts of Interest: The authors declare no conflict of interest or competing interest.

Appendix A

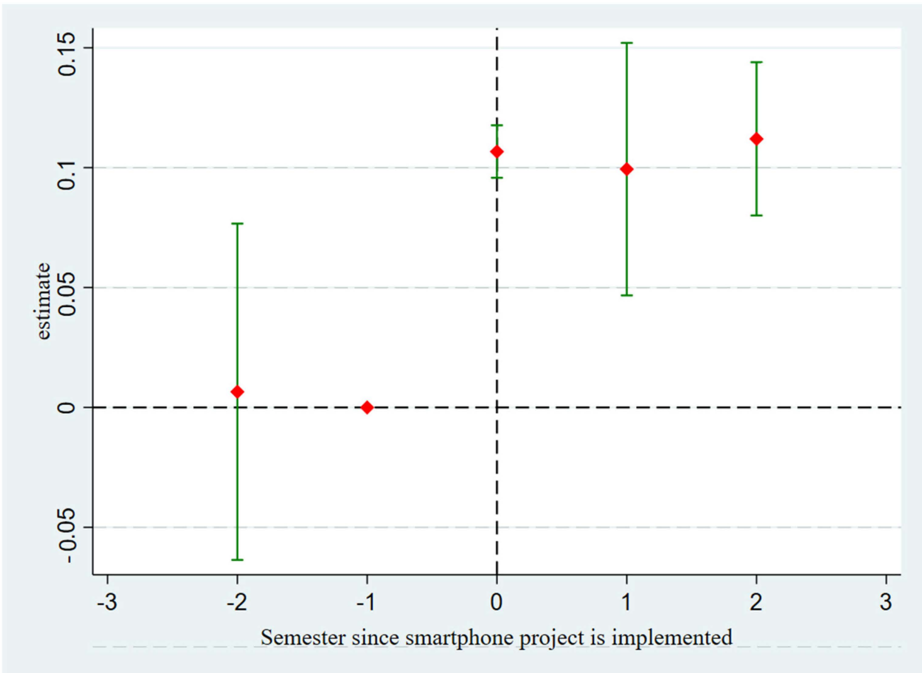

Figure A1. The results of the parallel trend test. Note. The estimates are presented on the *y*-axis, while the *x*-axis represents the semester before and after the intervention. The negative values on the *x*-axis indicate the semesters before the intervention, while the positive values are for after the intervention.

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