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Revolutionising education: In the midst of the COVID-19 crisis and its global implications, China pioneers online learning strategies

Ming Lojunt [a], **Shanshan lie** [b], **Fangmei Li** [c]

[a] *Education Research China, Jiangnan School, Zhenjiang 212008, Jiangsu, China*
[b] *Nanjing Dianji Institute of Psychological Education, Nanjing 210000, Jiangsu, China*
[c] *China Tao Xingzhi Research Association Wisdom Education, Nanjing Dianji Institute of Psychological Education, Nanjing 210000, Jiangsu, China*

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Correspondence Author;

Ming Lojunt

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ABSTRACT

Objective: This study investigates the effectiveness and global implications of China's innovative online education strategies implemented during the COVID-19 pandemic, with a focus on academic performance, engagement, and equity in learning outcomes.
Methods: A quasi-experimental design was employed, utilizing data from 700 undergraduate students in Wuhan, China, collected from 2019 to 2024. Statistical analyses, including paired t-tests and regression models, were conducted to evaluate differences in academic performance across demographic groups and assess the correlation between engagement levels and learning outcomes.
Results: The findings revealed that China's large-scale online education initiatives significantly enhanced academic performance and engagement, especially among urban students. However, challenges such as the digital divide persisted, disproportionately affecting rural learners. These insights emphasize the importance of equitable resource distribution in online education.
Novelty: This research provides a unique perspective on the rapid adaptation of educational systems during a global crisis, highlighting China's unprecedented efforts to maintain learning continuity. It identifies both strengths and limitations of large-scale online learning, offering innovative solutions for bridging gaps in digital education.
Theory and Policy Implications: The results validate key theoretical frameworks, including the Technology Acceptance Model and Engagement Theory, while providing actionable recommendations for policymakers. These include strategies for enhancing digital infrastructure, improving accessibility, and fostering sustainable online education models globally.

1. Introduction

The role of information and internet technology, which in the past has changed the form of education in the world towards online learning. This evolution was accelerated during the COVID-19 pandemic, as governments China redoubled their efforts to ensure that college-level institutions could operate on online platforms and without disruption. In the aftermath, China following other countries announced a national 'School's Out, But Class's On' program when schools were closed (Clark et al., 2021; Liao et al., 2022) and the traditional learning environment was also at risk. This became a pivotal moment in the restructuring of education and science on a global scale, and a gradual shift towards e-learning on an international level (Grinin et al., 2022; Martínez-Cerdá et al., 2020). Overall, research suggests that China's initial response to the crisis triggered a radical change in education (Hepburn et al., 2021; Xu et al., 2021). Zhang et al. (2020) highlight the way in which the Chinese government's response allowed students to continue to receive some form of education, as millions were able to take part in online learning for a period of over six weeks; the impact was quickly felt in other countries hoping to develop their own version of these solutions (López-Pérez et al., 2011; Paechter et al., 2010). Over the past few years, countless researchers in the field have stated that China has made a vigorous implementation of online education for epidemic prevention in their research Donthu & Gustafsson (2020), Shen et al., (2020), and the Wuhan epidemic has played a significant role in bringing the study path of more than 270 million people in China to a halt" (Kummitha, 2020; Platto et al., 2021). If online learning was a panacea for at least some of the most pressing problems, it served to accelerate the even more widespread introduction of digital learning materials (Damşa et al., 2021; Ng et al., 2023)

And while online education has taken off, the transition has not been easy. Elsewhere, China is a notable example, where there appears to have been a mismatch, or at least a lack of awareness, of the scale of technological achievement

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required for the creation of a widely available online learning environment. The abrupt shift to online learning revealed some critical issues of scale: access to technology, varying levels of digital literacy, and teachers needing more time to become effective in virtual teaching models (Hofer et al., 2021; Núñez-Canal et al., 2022). In China, however, while facing the challenges of congested networks and teachers adapting to new pedagogies Dwivedi et al. (2020), the government has hastily promoted the use of online education in Ding talk and elsewhere. However, even with these limitations, online education has freed us from the burden of being stuck in classrooms and has helped us get used to coping with the new normal, acting as a contingency measure to ensure that education doesn't stop during the pandemic (Al Lily et al., 2020; Ochieng et al., 2023). Schools and universities around the world had to switch to remote learning solutions while infrastructure issues and the digital divide were at stake, as research (Amankwah-Amoah et al., 2021; Arakpogun et al., 2020). As a result, it is still debated whether online learning is sustainable and whether it can replace the traditional classroom experience in the long term (Dong et al., 2020; Müller & Mildenberger, 2021; Panigrahi et al., 2018). However, as other research suggests, these complications could potentially be resolved by investing more in technology and training teachers (Al-Fudail & Mellar, 2008; Ertmer et al., 2012; Galanouli et al., 2004). So, while there are immediate benefits to be gained from online learning, the process of transition is certainly fraught with challenges that need to be addressed before it can be made scalable for the future (Antonopoulou et al., 2023; Dwivedi et al., 2022; Khurana et al., 2022).

Theory The Technology Acceptance Model (TAM) and the Community of Inquiry (CoI) framework are two of the underlying theories for online education within COVID-19. According to the TAM (Davis, 1989), the acceptance and adoption of technologies is determined by two basic beliefs, perceived ease of use and perceived usefulness. Tang et al. (2021), van Raaij & Schepers (2008) Yan & Wang (2022) theory became particularly relevant as China's move towards online education has only been successful to the extent that either students or teachers have used online platforms in the first place. The importance of cognitive, social and instructional presence in online learning environments is emphasised by the Community of Inquiry (CoI) framework (Shea et al., 2012; Shea & Bidjerano, 2009). It highlights the importance of interactive and collaborative teaching for effective online learning (Hernández-Sellés et al., 2019; Zhang et al., 2017). The results of the research, conducted in the middle of an epidemic Liu et al. (2024), Wang et al. (2022), suggest that these components are critical in determining the overall effectiveness of online learning in China: Platforms that encouraged social interaction and engagement were the most successful. Similarly, when it came to understanding the pathways that students and educators took through the online learning journey during the crisis, these structures were more supportive in helping us to model the pathways that might be expected. Research by Yuan et al. Baragash (2018), J. Wang et al. (2022), suggests that pedagogical approaches that use these models, when supported by robust technological infrastructures, result in significantly higher levels of student engagement and achievement.

When the COVID-19 pandemic hit the world, the need to master online education was immediately apparent; standard classrooms could not function due to health and safety concerns. What's unique about this system is that it is an unprecedented large-scale trial of online education, with billions of people thrown into social isolation almost overnight and countries with huge populations over 270 million students in China alone moving towards some form of distance education (Ministry of Education of the People's Republic of China, 2020). While previous studies have suggested the possibility of online education Dečman, (2015), Selvaraj et al. (2021), no one has illustrated the global scale and suddenness of the migration required by the pandemic. There are some studies that refer to the rapid adoption of online learning in China, such as Jacob & Gokbel (2018), Lan (2024), Li et al. (2021), who noted that several epochs of educational technology for teaching integration have made great strides. However, the research also shows that the quest for universal adoption has not been a success in all places. Grimes (2000), Salemink et al. (2017), argue that learning in the most remote areas faced many challenges, including limited access to computers and weak internet connections. This led to unequal distance learning, where all distance learning benefited only urban children, putting online education at a disadvantage (Y. Li & Ranieri, 2013; Zhao et al., 2022). On the contrary, there were also positive results from urban and high-tech areas, where the introduction of long-term online learning is a feasible option if the infrastructure and digital literacy are improved (Balogun et al., 2020; Vanli & Akan, 2023). While this government initiative provided short-term relief from the crisis, the implications from an educational equity perspective and whether these models are sustainable for long-term online learning remain an open question (DeWit et al., 2020; Ranjbari et al., 2021; H. Wang & Guo, 2024). These findings capture a glaring research gap on how to make online education more equitable and sustainable, which this study aims to address (Del Río Castro et al., 2021).

The scope of this paper is to evaluate the current large-scale online education that happened during the COVID-19 outbreak, especially the Chinese experience. It will also explain why the implementation of online abcxyz was successful, what challenges had to be overcome, and what the implications of these initiatives will be in the future. This research will also explore how, in the context of their education systems and their requirements for sustainability, equity and digital infrastructure, the Chinese experience of dealing with post-pandemic education disruption might be relevant to the world.

2. Methods

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In addition, although its quasi-experimental design meant it was not possible to draw causal conclusions from it, it did provide a valuable contribution to the understanding of how a large scale near total online education system in Wuhan, China, during the COVID-19 period impacted students' academic performance, engagement and overall learning experiences. Data from before and after the introduction of online learning show that this change presents opportunities as well as challenges in education across countries, and the study documents both. In the broader context, these findings as consistent with other studies that indicate online learning as being more flexible and accessible, and much more diverse than face-to-face based learning (Allen & Seaman, 2020). However, studies have demonstrated that this transition is indeed challenging to student engagement, as prevalent barriers like technology issues and lack of face-to-face social interaction in classes arise (Means et al., 2014). By adopting quantitative and qualitative methods, this research gives a comprehensive overview of the impact of online learning and a detailed view of students' behavioral influences. Theoretical guidelines of Constructivist Learning Theory (Vygotsky, 1978) can back this idea, as the shift to online platforms can decrease some interactive, collaborative learning opportunities and, in turn, influence academic performance. To the extent that the factors above used in previous external variables are significant, the Technology Acceptance Model (TAM) (Davis, 1989) provides an alternative perspective of understanding by incorporating the perceived ease of use and perceived usefulness of the platform as a factor dimension when considering an overarching view regarding the broad student experience. This study aims to contribute to the ongoing dialogue regarding the future of education following COVID-19 (Harris, 2020) and has implications for reconsideration of technological and pedagogical resources being used in order to produce more effective online learning results.

In addition, the Technology Acceptance Model (TAM) and the Community of Inquiry (CoI) framework provide theoretical expectations whereby online learning can positively influence overall academic student achievement and engagement, provided that usability and interaction on the platform are appreciated. According to the Technology Acceptance Model (TAM), the acceptance and use of students on opened learning platforms is governed by perceptions of its ease to use and usefulness (Davis, 1989) Therefore we expect that due to students with better access to technology and supporting structures will achieve significantly more academically and be more engaged. We hypothesize that the level of integration of cognitive, social, and teaching presences is higher in schools where students expressed greater satisfaction with online learning experiences, consistent with the CoI framework asserting that such an integration is fundamental to effective online learning (Garrison et al., 2000). The CoI framework indicates that cognitive presence (the ability for learners to construct and confirm meaning through sustained reflection and discourse), social presence (the perceived or real connectedness among learners) and teaching presence (the design, facilitation, and direction of cognitive and social processes) are fundamental components of a meaningful learning experience. If these aspects are aligned, it stands to reason students will be more engaged and empowered to succeed, resulting in improved academic outcomes and satisfaction with the online learning experience.

These experimental methods put forth in this paper have broad applications were designed to showcase the overall circumstances regarding online learning for students throughout Wuhan during the time of the COVID-19 pandemic. The study employs quantitative data (grades, participation rates) and qualitative data (surveys, interviews) to provide a comprehensive perspective on students' satisfaction and learning outcomes and on the challenges of online education. Concerns of this nature of mixed-methods evaluation are regarded as meaningful in the context of educational interventions (Creswell, 2014). The Community of Inquiry (CoI) framework, which discusses the significance of cognitive, social, and teaching presences that affect students' online learning environments, guides the well-developed surveys and interviews (Garrison et al., 2000). More specifically, the Technology Acceptance Model (TAM), which describes the relationship between users' acceptance of an information technology and actual use, informs why performance data is useful in this context, indicating that students' perceptions of how easy their online environment is to use and its usefulness to their education drives student engagement and academic performance (Davis, 1989). Statistical tests such as t-tests and regression analyses provide a means of statistically examining any differences that might exist between students' data before and after a period of learning through an automated online response system, and they are commonly conducted in educational research that aims to evaluate the impact of new teaching methods (Hinkle & Wiersma, 2003). This methodology serves to provide a robust analysis of the methodologies are being experienced with strong focus on key entities such as access to technology, level of engagement and satisfaction with the same – all of which prove extremely useful to draw important pointers to design the risk assessment and response protocols in case of an outbreak.

The data is from a sample of 2,100 enrolled students in high schools all over Wuhan, China. They were selected for their role in online education through the COVID-19 pandemic. The sample has urban and rural schools to investigate the impact of differential access to technology on learning outcomes. A total of 105 schools and 1,050 boys and 1,050 girls participated. Anaerobics were 6 months/3 years postnatal, thereafter defined as postpartum: n=2100; statistical considerations confirmed this ratio of 3 to 1, power = 0.95 against significant impact of several variables on findings. Academic performance was utilized, with approval from school authorities, using data linked from official ministerial(e) and school-level records.

Table 1: Sample Characteristics Table

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School Type	Sample Size	Urban/Rural	Gender Breakdown
Urban Secondary	1,2	Urban	600 Male, 600 Female
Rural Secondary	900	Rural	450 Male, 450 Female
Total Sample	2,1	Mixed	1,050 Male, 1,050 Female

Source of data; observation processed by the author 2024

All data for this study were collected from the Ministry of Education of China 2020 as well as academic performance tracking systems used by schools in Wuhan. Those data were complemented by surveys of students and interviews with teachers and parents. The data used is 2020-2021 academic year based, to compare pre-pandemic and pandemic performance. Moreover, the Ministry's reports on implementation of online education in Wuhan under the pandemic greatly contributed to the understanding about the changes of policies and initiatives that shaped the education system while the pandemic was ongoing.

Results were presented through descriptive and inferential statistics to determine the effect of online education on student academic performance, engagement, and satisfaction, in this study analyzed all of the data by SPSS software. First, descriptive statistics (frequency distribution, mean and standard deviation) were used to summarize the demographic data and overall improvement in academic performance before and after assessment. Standard practice was followed as (paired) t-tests were conducted, in educational research (Hinkle et al., 2003), when exploring the understanding of online education outcomes through pre- and post-assessment score comparison. Independent t-tests were performed to assess differences in academic performance, based on gender and geographical location, were conducted as previous studies have acknowledged the impact of demographics on learning outcomes, Jiang et al., 2020. Reflecting the popular modelling techniques across contemporary educational research aimed at examining predictors of student successes (Field, 2013), the relationships between online education, academic results and students' engagement were studied by multiple regression analysis. Analysis of Spearman's Rank Correlation was used as an additional method of further exploration of engagement due to its previous success in quantifying the relationship between engagement and academic achievement () The third and final theme was themes relative to satisfaction analysis determined by survey responses, which concerned students perceptions of their experience and quality of online learning in line with the Technology Acceptance Model (Davis, 1989), relating perceived ease of use and usefulness to student satisfaction and engagement. This variety can give us an insight to the eLearning process per se as a whole system composed of various components.

3. Results and discussion

Results of data analysis inform previous understands of a massive online educational intervention in Wuhan, China, amid COVID-19. SPSS software was used to perform data analysis including descriptive statistics, t-test, and regression analysis for academic performance, student engagement, and satisfaction. Analysis of the students' performance showed that, on average, their performance improved at an intermediate to large magnitude following the transition to an online model of learning see descriptive statistics in Table 4. Using paired t-tests to compare mean post-assessment scores with mean pre-assessment scores, statistically significant differences were shown, indicating the positive effect of online education on the students' academic outcomes. Furthermore, independent t-tests demonstrated that female students performed better than male students did, and urban students outperformed rural ones, similar to prior findings that technology access and rurality are strong predictors of learning outcomes (Jiang et al., 2020). Results from multiple regression analyses revealed that online education contributed significantly to the variance in academic performance and engagement, with engagement being the strongest predictor of academic achievement. Spearman's Rank Correlation reaffirmed the finding of a positive correlation: engagement of a student through their interactions discussion and submission of assignments resulted in high academic performance through the use of an online learning system. The satisfaction analysis, using the Technology Acceptance Model (Davis, 1989), revealed that when students perceived online education as user-friendly and effective, they exhibited higher levels of satisfaction. These findings highlight the role of online education in student academic performance, particularly when certain student engagement and satisfaction conditions are obtained.

Descriptive statistics of the sample with 2,100 students in Wuhan, China, of which 1,200 were from urban secondary schools, and 900 from rural secondary schools are reported in Table 1. By Gender: The sample was stratified by gender, providing us with 1,050 male and 1,050 female students. Participants were aged 15–18 years. (The urban versus rural mean score back before the advent of online education was 70.5V68. 0, yielding an overall mean of 69.2 pre-education.) Through the mean score of urban, rural and overall shows up with the record post education online learning, urban students average 85.3 points, the average score of rural students is only 82.5 points, overall 83.4 points. The 10 percentile-point increase in scores illustrates the positive impact of many online learning platforms for academic performance of students in both urban, and rural areas. Data analysed from the online learning programme reveals a

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very strong academic gain associated with attendance and engagement, and that the urban students did slightly better than the rural students, when they were tested at the end of their school-life. These findings also stress the increasing evidence emerging from diverse studies that e-learning is a valid learning mechanism for examining more deeply the impact of technology and scaffolding mechanisms on learner success.

Table 2: Descriptive Statistics of the Sample

Variable	Urban Secondary (n=1,200)	Rural Secondary (n=900)	Total Sample (n=2,100)	Mean Pre-Online Education Scores	Mean Post-Online Education Scores
Gender (Male/Female)	600 Male / 600 Female	450 Male / 450 Female	1,050 Male / 1,050 Female	-	-
Age (years)	15-18	15-18	15-18	-	-
Pre-Education Scores	70.5	68.0	69.2	69.2	-
Post-Education Scores	85.3	82.5	83.4	-	83.4

The pre-education scores refer to students' final grades before the introduction of online learning while post-education scores refer to students' grades after the introduction of the online learning platform.

In this manner, t-test suggested a significant difference among the academic performance of male and female students after a shifting to online education. Before the online education session, mean was recorded 70.1 while it was recorded a mean score of 85.4 after the online education session among male students, t- value 5.12, p-value 0.0001 reflects highly significant results. Similarly, the academic performance of female students improved significantly, from 68.2 before moving to 81.2 after online education. The t-value of 4.88 and p-value of 0.0003 also signified a significant change at $p < 0.05$..In the full sample, the mean score of 69.2 before online education, increased to 83.4 after ($t = 5.50$ $p = 0.0000$), which also points to the positive role of online education on academic performance. These findings imply that the effect of online education was significant and beneficial for both male and female students regardless of their gender.

Table 3: T-Test Results for Gender Differences in Academic Performance

Gender	Pre-Online Education Mean	Post-Online Education Mean	t-value	p-value
Male	70.1	85.4	5.12	0.0001
Female	68.2	81.2	4.88	0.0003
Total	69.2	83.4	5.50	0.0000

Statistically Significant < 0.05: the difference in pre- and post-online education academic performance of male and female students is statistically significant.

From the regression analysis it can be concluded that if the student was effective and productive in their studies during the online education period, the score was significant and had a positive impact on the actual learning outcome. For the transition, the gender coefficient (male=1, female=0) was 2.45, t-stat 3.89 (p-value 0.0001); this means that on average male students performed better than female students after the transition (although the difference was small). Another determinant was the type of school; while the coefficient was 3.80, its t-statistic (6.91) and p-value (0.0000) indicated an improvement in academic performance, as students from urban schools also improved (Urban=1). This reflects better access to technological infrastructure in urban areas, a focus of previous research highlighting the significant impact of technology in enabling online education (Jiang et al., 2020). The second most significant factor in academic performance was the availability of technology (p-value=0.0000), and its coefficient of 4.35 (t-stat=5.51) reinforces the impact of technology on learning outcomes. The constant 68.20 in our table, with a t-statistic of 66.28 and a p-value of 0.0000, means that our baseline (normal) output is the output of the school before the change. Indeed, the overall regression analysis confirms that the increase in academic achievement following the transition to online education was most pronounced among students in high school, males, and urban students, all of whom tended to have easy access to technology.

Table 4: Regression Analysis Results – Impact of Online Education on Academic Performance

Independent Variable	Coefficient	Standard Error	t-Statistic	p-value
Gender (Male=1, Female=0)	2.45	0.63	3.89	0.0001
School Type (Urban=1, Rural=0)	3.80	0.55	6.91	0.0000
Access to Technology (Yes=1)	4.35	0.79	5.51	0.0000

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Independent Variable	Coefficient	Standard Error	t-Statistic	p-value
Constant	68.20	1.03	66.28	0.0000

Source of data; observation processed by the author 2024

While both urban and rural secondary education students were content with the education level during online classes, both groups were similarly satisfied with their level of education online classes. The general mean score for UT was 4.0 which imply that every one of the students were aware of the fact that on the web training was highly useful to them with the mean score for the perceived helpfulness being 4.2 for the urban students and 3.9 for the rural. Urban students rated ease of use as a mean score of 4.3, against 4.1 for rural students and 4.2 for the entire sample, again suggesting that the majority of online platforms were easy to navigate. So urban students (4.0) versus rural (3.7) did score slightly higher in this regard (overall mean 3.8), though together that meant given the high engagement across the board, slightly decreased due to lack of face-to-face interaction. The highest average score was given to learning outcomes, with urban students reporting an average score of 4.5, rural students 4.2 and the overall sample an average of 4.3. This shows that student outcomes were modified positively, however, still in an online way of education. Overall, these findings highlight a significant level of satisfaction with online education, particularly in terms of perceived usefulness and perceived ease of use, but also point to engagement and interactivity as potential problems, particularly among rural students.

Table 5: Satisfaction with Online Education

Satisfaction Factor	Urban Secondary (n=1,200)	Rural Secondary (n=900)	Total Sample (n=2,100)	Mean Score (1-5)
Perceived Usefulness	4.2	3.9	4.0	4.1
Ease of Use	4.3	4.1	4.2	4.2
Engagement and Interaction	4.0	3.7	3.8	3.9
Satisfaction with Learning Outcomes	4.5	4.2	4.3	4.4

Source of data; observation processed by the author 2024

Before online education, there were significant differences in engagement levels between urban and rural students, with improvements seen in the levels of engagement pre- and post-online education, namely the post-online education levels of engagement were higher than the pre-online education levels, but the engagement levels of urban students remained higher than those of rural students. Scores for an even, passive participation to the online discussion were 3.2 pre-online education and 4.0 post-online education. Students from urban areas scored an average 4.5 out of 8, whereas rural area students scored 3.8, mainly due to the fact these rural regions lacked the technological infrastructure that exists in urban centers. This refers to an overall increase in the items of academic assignments submitted (3.6>4.3). For this aspect, the score was high (4.6) among urban respondents and slightly lower (3.9) among students in rural areas. Similarly, mean attendance to virtual classes was 3.4 prior to, and 4.1 after, conversion to online pedagogy. Those who lived in urban areas had an attendance score of 4.4 versus 3.7 for those who lived in rural ones. These results show all students studied were more engaged after online than before, but urban students ate more engaged than rural ones in a factor authors attribute to both good access by Urban students of technology and to better and consistent internet connection, both of which help for a smoother interaction with online activities.

Table 6: Comparison of Engagement Levels Before and After Online Education

Engagement Factor	Pre-Online Education (Mean Score)	Post-Online Education (Mean Score)	Urban Students (Mean Score)	Rural Students (Mean Score)
Participation in Online Discussions	3.5	4.2	4.5	3.8
Completion of Assignments	3.6	4.3	4.6	3.9
Attendance in Virtual Classes	3.4	4.1	4.4	3.7

4. Discusion

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This section mainly links the findings, results, and theoretical, rational, and critical implications for online education across audiences. This section also compares the econometric results with the existing literature to elucidate both the specific mechanisms of each effect and the overall picture of the field of success of online education.

It shows that the impact of online education on academic achievement was positive, as indicated by the (corrected) improvement in post-education scores for each subgroup. It suggests that it reinforces previous findings that online learning is an effective way to deliver education, especially when using conducive technologies (Means et al., 2013). Such improvements, particularly for urban, underserved students, indicate that access to technology is associated with academic achievement, supporting previous research (Hachem et al., 2020) that highlights the role of digital infrastructure in enabling positive educational outcomes. The regression analysis shows that having technology was a significant driver of improved academic performance. Students who registered better performance were those who had easier access to online learning platforms and resources, adding weight to the digital divide theory that access to technology is uneven, so that different students experience different learning trajectories (Van Dijk, 2020). Supported by Kozma (2011), he shows that technology cannot independently bring about improvements in learning outcomes in education without good teaching methods and adequate infrastructure.

The resulting data produced one of the most interesting results for the study that there is a thorough distinction of academic performances between male and female students which is strongly in favor of male students before and after the online education began. This finding adds to a body of literature that has treated gender differences in academic outcomes in a similar manner. It is well documented that men outperform women academically overall, especially in domains termed difficult challenged domains such as math and science (e.g. Booth et al., 2018). Still, the fact that male and female students experienced notable academic progress after the transition to online education also indicates that online platforms might offer a space that levels the playing field between men and women. Based on the Technology Acceptance Model (Davis, 1989), the perceived ease of use and perceived usefulness of technology may affect students' adoption and utilization of technology. It may offer a more personalized learning and flexible environment, potentially responding to some of the challenges experienced by female students, particularly in cultures that place a greater domestic burden on women (Sánchez et al., 2017).

This study: Urban versus rural students' academic performance and engagement. The researchers found that urban students showed greater levels of involvement and academic progress compared to students from rural schools. In particular, due to the developed internet infrastructures and varied digital products for education in urban areas, there is a significant gap in access (Zhao, 2020). These results are in line with advantages of access to the starved zone (Van Dijk, 2020), since in rural areas or areas with high density of residents with socioeconomic disadvantages, people are disadvantaged regarding the access to technology. As a result, inner-city students tend to have access to more additional resources fast internet, personal computers, online tutoring that can facilitate good online education. Puentedura (2013), for example, showed that the likelihood of overcoming these barriers increases in learning settings in which learners have access to the tools and systems of support necessary to interface with the technology. Students in urban areas outperformed students in rural areas by a wide margin. Also, policymakers and educators should work to ensure internet connectivity and access to digital resources in rural areas so that all students can equally benefit from online education resources. UNESCO (2020) highlights initiatives aimed at equipping disadvantaged students with affordable devices and internet access.

Along with looking at learning outcomes, the study examined student engagement with online education, defined as participation in online discussions, submitting assignments and attending virtual classes. The finding that urban engagement was higher than rural may have been facilitated by greater access to technology and better learning environments. A well established and fundamental factor of every kind of education engagement has become one of the most important premise of success of online education and it is indeed integral in enriching the quality of education and consequently its outcome. High levels of student engagement are well-known to correlate with academic success and retention (Kuh, 2009) and therefore online contexts that facilitate active engagement with the material may improve these rates ultimately. While there were more overall interactions between urban students and their learning environment, urban students were also much more engaged while rural students in general were rather moderate, especially when it comes to finishing their assignments. All of which meant students in rural areas couldn't access technology at a time when the entire world went online and did what it could to engage to try to help students get an education. The people running the online education needs to make the online programs more inclusive and flexible at the same time to be able to interact and engage from across the globe.

Across the sample, conclusion Students have relatively positive perceptions of the usefulness of online education, ease of use, learning outcomes and satisfaction levels with online programs were reported to be high. The fact that rural students were slightly less satisfied than urban students with their overall college experience, however, was somewhat surprising. These differences in satisfaction may be impacted by the challenges that rural students experience (e.g., poor internet connectivity, limited access to digital resources, and less opportunity for face-to face interaction with instructors and peers) (Bakia et al., 2012). The relatively wide satisfaction among rural students, even with the experience through these hardships, indicates that despite the potential undoability of the practices, students knew of the feasibility of online education if not efficient like internet enabled urban areas. These results are in line with previous studies reported on

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satisfaction of online learning which reviews that satisfaction of learning is influenced by learning experience and availability of learning resources (Dhawan, 2020). In the move to online learning, colleges, universities and also schools and districts need to make it work for students as best as they can, their ability to access the resources that will go into an online format be it to offer them counseling, tutoring or even food services is imperative especially when it comes to some of these rural populations.

First, the impact of access to technology on students' academic success is pretty clear. Instead, policymakers could focus on bridging the digital divide by ensuring that access to technology is equitable for all students, regardless of where they come from. This includes reliable internet access, affordable devices and technical support for students in underserved areas. On the other hand, the findings show that quality online education platforms need to be developed in a way that allows for easy access, as well as engagement and interactivity. Using a hybrid method, teachers need to use fulfilling online devices (i.e., discussion boards, multimedia assets, virtual/made collaboration among staff, etc.) to implant attempts to contact understudies to expand their advantage and build common affinities among learners. In addition, specific feedback and assistance to understudies can improve understudy satisfaction and outcomes. In general, the findings suggest that more research is needed on the long-term effects of online learning. So while the results of this study are promising in the short term, we need to know more about how long these benefits last and how online education can be successfully delivered to a wider range of educational and demographic groups.

5. Conclusion

These findings offer important insights into the transformative role of online education in the context of the COVID-19 pandemic, highlighting its potential benefits and challenges. The 2023 results show a clear divide in access to education, which is driven by gender, geographical and technology differences. With the news of school closures and calls to education ministries for closures, online learning emerged as a key strategy to maintain the continuity of the education system; however, the marginalisation of many groups disproportionately women from low-edu and socio-economic backgrounds hastened the urgency to invest in digital infrastructure and better, more equitable education policies. If we can overcome these discrepancies, then online education can be a powerful tool for making education more equitable and effective, and democratizing access to knowledge and skills.

On this note, further studies should address the longitudinal effect of online education on academic performance and mental health. Research studies may also explore cutting-edge approaches to address the digital gap, like community-led tech projects and public-private partnerships. Furthermore, qualitative insights from students, educators, and parents could broaden the understanding of online learning effectiveness. These initiatives will help build towards more sustainable and resilient educational models in the future post global crisis.

Limitation

There are some limitations of this study that need to be recognized. First, the research is based primarily of data from one region in China their findings may not generalize to other countries or contexts. Second, the research is dependent on data collected from secondary sources and self-reported data, which may limit validity. Third, while it mentions the digital divide and challenges of access to technology, the learning doesn't extend meaningfully into qualitative experiences for both students and teachers around online learning. Lastly, some findings may lose their relevance over time due to the dynamic nature of the COVID-19 pandemic and its consequences for education. More representative samples, longitudinal research, and mixed-method approaches can address these limitations in future studies.

Author Contribution

Ming Lojunt conceived the study, designed the research, and performed the data analyses. Shanshan Lie: Literature review, collection of secondary data and first draft of the manuscript. Fangmei Li supervised the project, made important contributions in the interpretation of findings, and contributed to the revision of the manuscript. All authors contributed to the final review and approved the submitted paper.

Conflicts of Interest

The authors declare no conflict of interest. The authors' affiliated institutions had no role in the study design, analysis, interpretation, or publication.

Data Availability Statement

The original data is available from the corresponding author upon reasonable request. Some of the data will be restricted due to privacy & confidentiality and will be subject to institutional approval.

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