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COVID-19-Induced Online Learning and the Associated Setback in High School STEM Education

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ABSTRACT

The COVID-19 pandemic posed a serious disruption to most of the world, and one of the most impacted systems was global education. As schools transitioned from in-person classes to online meetings, many students began to lose motivation or develop internet habits that proved detrimental to their education in the sudden quarantine. Online learning caused a lack of face-to-face interaction, causing a multitude of academic and social issues. Inequities such as the discrepancies of internet access and varying degrees of familiarity with online learning also caused student setbacks. A lack of accountability with device-based online learning had also caused an increase in cheating incidences. In the present, post-pandemic world, education has returned primarily to an in-person classroom setting. However, the consequences of the period of online learning are becoming apparent as students progress and learn more advanced material. In particular, academic setbacks seem to be more apparent in STEM subjects as opposed to those of the humanities and arts. In this review paper, online learning and its overall effects, both past and present, are investigated.

Introduction

The outbreak of the COVID-19 virus in 2020 triggered a global crisis that severely impacted the traditional education system (Herrick et al., 2022). Students and teachers alike were forced to quarantine due to the unknown and unquantified risks to public health. The physical school closures were estimated to have affected 95% of the world's student population. The world had not seen such an educational institution lockdown since World War II (d'Orville, 2020). The lockdowns also restricted students' physical activity and their ability to interact with their peers or engage in extra-curricular activities, which has been shown to have negatively affected their mental and physical healths (Bethäuser, 2023). It has been said that the switch from a traditional classroom setting to novel online learning has proven to be one of the greatest challenges to the education system at large (Daniel, 2020). The lack of education from the disruption of the established systems also had significant long-term effects on children's long-term well-being (Reuge, 2021). Students are constantly changing individuals, and thus, they are more susceptible to mental health consequences than adults. With the forced quarantine from the pandemic, students were more at risk for developing anxiety and depression (Sau Man Ng, 2022). Due to the recency of the Covid outbreak, the full extent of these detrimental academic and social effects to students has yet to be seen.

There are already signs of negative academic outcomes of students during pandemic learning. According to Dorn and her colleagues, the curriculum covered during COVID-19 for K-12 students were, on average, five months behind in mathematics and four months behind in reading compared to historical curriculum data. These statistics were scattered, however, as a greater discrepancy was noted amongst students of lower socioeconomic status and students of color. These students were shown to have the greatest delay in their academics when compared to students prior to the pandemic. (Dorn et al., 2021). Standardized test scores from the pandemic-induced online learning years were also significantly lower than the years before the pandemic across all K-12 grade levels, with test results in mathematics more significantly affected than those in reading. More importantly, these trends seem to have persisted even as students have returned to in-person learning (Pinto, 2023). This has been quantified by the standardized testing

data when comparing scores from 2021 to 2019. Student passing rate averages saw a 12.8% decline in mathematics and a 6.8% decline in English and language arts between those two years. These declines had been shown to be more drastic in districts that were slower to offer in-person learning, indicating a correlation between in-person learning and passing rates and revealing that certain communities were more academically impacted by the pandemic than others. (Jack et al., 2022).

Before the pandemic, STEM education was considered highly valued due to the rapid technological advances made. STEM education's ability to equip students with crucial modern-day skills such as critical thinking, problem-solving ability, innovation, and collaboration were required in a world that is becoming more and more technologically savvy (Li, 2019). However, when the COVID-19 pandemic first broke out, general understanding of STEM subjects played a pivotal role in governing the issue (Kollosche & Meyerhöfer, 2021). Thus, it is, now more than ever, crucial that we realize the importance of STEM education as a whole in society. When a vaccine was successfully created to fight off COVID-19, people were eager to receive it and the general sentiment regarding the vaccine was positive. However, as time went on, people began to doubt the vaccine and its efficacy. Vaccination rates began to lower, which, in turn, caused another surge in hospitalizations and deaths. It is possible that this mistrust in the vaccine had stemmed from the shortcomings of STEM education during online learning (Lupinacci & Wolfmeyer, 2024). It can be argued that a strong education in biology and the nature of science would help the public trust vaccines, so that doubt and mistrust in the science community can be minimized (Reiss, 2022). As students become more exposed to quality STEM subject education, they can further their interests in STEM-adjacent subjects that require a basic understanding of math and science, such as healthcare, engineering, and design (Engelbrecht, 2023).

In the years prior to the pandemic, digital devices had slowly been introduced into the school system and had changed the context of teaching and learning with access to the internet and technology (Yates et al., 2020). Online learning is defined as any learning experience that involves interaction with or is mediated by digital technologies (Kuhlman et al., 2024). However, the sudden shutdown caused by the pandemic caused schools and districts across the globe to face the daunting challenge of converting their instructions entirely online as swiftly as possible. Even with digital learning experience, schools struggled to adapt (Young & Donovan, 2020). Moreover, online learning causes students to have more time and access to the internet, which can cause internet addiction. Internet addiction is a form of technological dependency that can ruin lives by causing neurological complications, psychological disturbances, and relational chaos. This problem is a rising phenomenon affecting people to varying frequencies around the world (Akin, 2010). In particular, teens are specifically susceptible to internet addiction (Lin, 2020). The expansive use of the internet has also evidently led to more opportunities for cheating, searching for answers online or utilizing the internet to obtain unfair advantages. In this review paper, the far-reaching effects of online learning will be investigated, with special attention given to the consequences of a lack of systemic preparedness, a widening gap of inequities, and a warping of student expectations.

Online Learning Deficiencies

As the pandemic forced schools to shut down around the world, the global education system began to implement online learning through different resources. Even in the past, virtually-based students have shown lower performance in mathematics than usual face-to-face schools. However, this is most likely due to both the lack of comprehension of the curriculum on the students' part and the lack of efficacy in delivering the curriculum information on the online platform's part (Choi et al., 2017). Although online learning materials can provide students with more opportunities without the restraints and limitations of a normal classroom, the benefits of a normal classroom are not guaranteed (Zwart et al., 2017). In teaching mathematics, the teacher should ideally have a positive and interactive environment for the students to fully utilize their capabilities. Certain barriers come specifically with online learning for students, including internal, external, and cross internal and external barriers. Internal barriers include a lack of understanding of mathematics, a lack of social interaction between students and teachers, and eye strain when using technology for online learning continuously. External barriers include poor internet access, lack of training using online learning, and

lack of instructional design. Cross internal and external barriers include the duration of learning and overload assignments (Noviani, 2021). Another issue is that learning mathematics online requires more interaction than other subjects. There have been multiple studies done to find better tools and techniques to utilize in mathematics online learning, but if it is too difficult to operate and use, teachers might be unwilling to use it (Alabdulaziz, 2021). Online learning is fairly new to both students and teachers, and the sudden switch from in-person to online proves to be an obstacle precisely because it is so new (Aziza, 2021). The novelty of online learning has caused new issues to arise, many that were never an issue before.

One of the main concerns, as previously mentioned, with online learning is the lack of face-to-face interaction between students and teachers as the shift to a virtual mode of education limited social contact and socialization routines, a central part of students' daily experience (Al-Maskari, 2021). This has, thus, revealed a need for tools and methodologies to support students' online learning, especially for students from lower socioeconomic backgrounds (Barana et al., 2021). In a study done by Mamolo, students' results show that their mathematics motivation and self-efficacy have significantly decreased over the 6-week pilot test of synchronous online learning. This has been shown to be partly caused by fear of asking for help in an online environment (Mamalo, 2022). Since there is less engagement, even if teachers offered extra help, many students would not accept the help. Moreover, in another study done by Rural, it was found that students were not motivated and slightly disengaged when facing an issue in understanding a mathematical problem or concept. This lack of motivation has caused students to avoid asking for help, leading to lowered academic performances (Rural et al., 2022).

Due to the decreased amount of interaction students have with their teachers and other peers, student interests, motivations, learning outcomes, and perceptions of online learning (academic perceptions) are negatively impacted (Ariawan, 2022). In particular, the student's emotions are strongly correlated to their learning capabilities. The negative emotions stemming from the pandemic and the sudden switch to online learning could have an effect on students' learning. In a study led by Tzaflkou, results suggested that negative emotions of boredom and cognitive load are significant predictors of students' acceptance of remote learning components. The more negative emotions a student has, the less they will be likely to achieve (Tzaflkou, et al. 2021). It is already clear that students are behind academically in mathematics because of the pandemic; however, this also handicaps their future learning of math. The math deficit caused by COVID-19 must be addressed before students can move on to higher levels of mathematics (Böhmer et al., 2022). It has also been found through Permana and others that continuous video conferencing via screens causes excessive fatigue. This phenomenon is known as "Zoom Fatigue" and can have a destructive impact on students' mental and physical health. According to their research, about 83.7% of students experience light stress, and 59.7% of students experience fatigue during online learning (Permana, 2023). This automatically lowers the quality of students' learning capabilities, since they are not in good condition.

Internet Usage Discrepancies

The digital age has already made irreversible changes to society, including dependence on the internet, but, with the pandemic, those changes intensified. Since society was forced into quarantine and isolation, the internet became the only way for people to converse and connect, increasing internet dependence severely. In a study done by Dr. Murat Tezer and his colleagues, it was found that students who had burnout from either parental pressures or high school success seemed to be more likely to develop internet addiction and internet usage was shown to have significant effects on a student's academic performance (Tezer et al., 2020). In a study done by Chou and Hsiao at a university in Taiwan, it was found when students were split into either addicted or non-addicted groups and given a survey, the internet addict group stated that the internet impacts their studies and life routines much more negatively than the non-addict group. This is because the students who have internet addictions spend all their time on the internet, and are unable to control their use (Chou & Hsiao, 2000). Dr. Zubair from Pakistan also conducted research to determine the impact of problematic internet usage on students' mathematical abilities and found that academic performance is shown to be negatively correlated with internet dependence. It is recommended that the internet be used as efficiently as possible

to avoid this consequence (Zubair, 2023). Additionally, it seems that problematic internet usage is negatively correlated specifically with students' mathematics achievements, indicating that there is some negative effect that internet addiction has on one's ability to learn or retain mathematics. Teacher-student relationships were found to affect student's self-evaluation levels on mathematics but did not directly correlate to student's actual mathematics performance (Zhou et al., 2020).

Online learning required students to learn from their own homes with either their own or school-provided devices worldwide. The issue with switching from traditional classrooms to an individual's home is the fact that not everyone's homes are equal. It has been shown that a combination of having both high income and high-speed Internet appears to be the biggest motivator to stay at home. The that the digital divide in the US appears to explain much inequality we observe in people's ability to stay home (Chiou & Tucker, 2020). A student doing schoolwork in their home located in less affluent neighborhoods would have very different results from a student doing schoolwork in a spacious and luxurious environment (Borba, 2021). Internet connection is also extremely vital to having smooth online learning experiences, but this is not something that all students have access to. In Zambia, research shows that more than 56% of the respondents did not have sufficient access to Information and Communication Technologies (ICT), electricity, and internet services. This is reportedly not only an issue in Zambia but also in Jordan and Bangladesh (Mukuka et al., 2021). In a study done by Bringula, it was found that half of the respondents did not have their own personal learning space for online sessions. 70% reported that Internet connection is the most problematic aspect of online learning (Bringula et a., 2021). In a study done in China by Clark and others, it was found that online learning showed some positive results; but only if the lectures were done by high-quality teachers. Furthermore, students performed better on computers than smartphones, but not all students have access to computers, making the circumstances unfair (Clark et al., 2021).

Questionable Student Ethics

The pandemic has had a negative impact on student's motivation and achievement. Specifically, younger children were more negatively affected in their learning than older children and children from families with a low socioeconomic status (SES) were more affected than children from families with a high SES. On top of this, low-performing students tended to be more affected by COVID-19-related school closures in mathematics (Hammerstein et al., 2021). This in part has contributed to cheating, as it is easier in an online environment due to the limited supervision giving way to various opportunities. From the students' perspective, the anticipation of less accountability for cheating in combination with difficulties to prepare for the online exams due to new family and community obligations emerging during COVID-19 or unfamiliarity with new exam formats might have increased the appeal to cheat in online exams. In fact, it was shown that students reportedly cheated more frequently on online exams than on-site exams (Janke et al., 2021). There are a variety of ways for students to cheat online. For example, students can wait for another student to take the exam and then obtain the answers using screenshots and emails, or students can take the exams together. Students can also claim that they received fraudulent error messages to acquire extra time to study or to get answers from another student. In addition, many unauthorized test banks from popular textbook publishers are available online and if given enough time to complete an assessment, students may be able to look up answers or find similar questions to gain an unfair advantage (Adzima, 2020). Students might also not be able to manage their time well in an online setting, resulting in minimal time to complete assignments, which could pressure the students and ultimately lead to cheating (Sevnarayan, 2024).

However, it is not only the students who feel that they are academically inept that cheat. Another study done by Sutrisno found that students cheat due to an unsupportive learning environment, lack of communication with teachers, and the overwhelming load of assignments. Although some students believed academic dishonesty was unethical, they still turned to cheating, as they were influenced by an environment that considered cheating natural. It was found that students with higher IQs committed academic fraud more often than those with average IQs, most likely because of their desire to keep succeeding (Sutrisno, 2020). The same goes for students with a higher socio-economic status;

these students most likely have more pressure on them to keep their status and are thus more motivated to gain an advantage (Alan et al., 2018). Students who begin to underperform at university have been shown a higher indication of cheating (Kurland & Siegel, 2013). One particular study done by Maras has determined that students most likely cheat due to the importance of achieving an education, the desire to succeed, and technological advances that favor academic dishonesty (Maras, 2022).

Discussion

The purpose of this study was to investigate the consequences of online learning, and how it has impacted the education system and its students. The pandemic caused the traditional education system to shut down, causing millions of students, teachers, and administrators to panic. The gathered findings suggest that online learning has impacted students of all years by leaving them behind by 1-2 academic years from where they should be. Overall, most studies have shown that students fell behind more so in mathematics than English, which is concerning as mathematics has been proven to play an important role in many aspects of one's life and teaches crucial skills. The most important part of the research, however, is the lowered motivations of the students and their capacity to commit academic fraud. Although these incidents spiked during the pandemic, if this loss of motivation continues, it can severely impact the student's academic career.

When the pandemic first broke out, it had been announced that school would be online-only for 2 weeks. However, the situation quickly became more serious than anticipated, and the entirety of the school year was shifted to online learning. What was supposed to be two weeks turned into almost a full 2 school years of attending class from home. Although some students had liked this in the beginning, it was clear that the lack of social interaction in the online classroom setting was causing many students to lose motivation to even attend their classes or do their work with integrity and honesty. During classes many students would simply open the computers and join the class meeting from their beds, and the teachers would not say or do anything to stop them. The interactions in class were also very scarce, as no student wanted to unmute their mics and ask their question in front of everyone else. Although there were office hours, many students felt scared to be on a 1-on-1 call with their teacher.

The perspectives and personal accounts of individual students cannot be used to describe all students during the pandemic. However, the prevalence of similar anecdotal evidence from authors around the globe reveals that there is definitely a need to confront and address the ongoing issue of delayed education, particularly in the STEM subjects. Much of the published literature regarding online learning during the pandemic details this discrepancy in the quality of education between the years before and after the global outbreak.

Conclusion

The pandemic is now in the past, but its effects are still very well experienced in the present day. Online learning was an inevitable short-term fix, since many expected the pandemic to last for a short period of time. However, it is now clear that COVID-19 is a long-term issue and the poorly handled situation of education should serve as an example that the education system must be better prepared to handle such global and serious issues (Naidu, 2020). The motivation loss that many students had felt during online learning is still prevalent. Internet addictions also still exist and are affecting the younger generations severely as they have been exposed to the media from a younger age. The rise in digital technology use during the pandemic may have made the industry more adept and productive, but its damaging effects are getting more clear as the younger generations get older. Digital schoolwork is also becoming more common, which might arguably be better since it is easier for students to make up work when absent, but in reality, this has irreversible effects. Students are becoming more and more reliant on digital tools such as spellcheck and are using more AI to do their homework. The laziness stemming from the pandemic combined with the development of technology are continuously ruining student's motivations and integrity. Most schools have also not addressed the fact

that there is a gap in student's learning from the online learning era, leading to students simply moving forward to harder topics without understanding the basics. Furthermore, the rate of students going to school remotely or online has also increased after the pandemic. Although homeschooling and online school have been options for many years already, many students did not think about taking those pathways because it was uncommon. However, the pandemic has shown that doing school remotely is possible and attainable to more students. Thus, more and more students are enrolling in virtual school or independent study since they know that it is much easier than the traditional classroom.

Considering the shortcomings and issues stemming from the current state of online learning, it has become clear that finding solutions to make online learning more interactive is vital for the future of the education system. However, the findings also point out that the academic gap that has affected numerous students all over the world must be addressed in order for the students to move forward in their academic careers. Additional academic supplemental classes could possibly be administered for students who have been more heavily impacted by the pandemic, and other solutions to address the existing learning gap should be researched more thoroughly. Furthermore, since the importance of STEM education has been emphasized, especially in light of the pandemic, there should be more implementation of core STEM classes in schools throughout the world to give students a better foundation to progress forward with their education. Limiting the access of online-based distractions from phones and devices in classrooms is essential, and implementing stricter rules when doing digital work to prohibit cheating should be prioritized.

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