

Impact of COVID-19 Pandemic on Engineering Education: Evaluation of Limitations and Recommendations for Effective Teaching

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Abstract

Numerous aspects of our lives were disrupted due to COVID-19, including traditional in-person education systems. The education system had to implement innovative approaches to meet the challenges COVID-19 brought upon traditional learning. The change in instructional methodology compelled instructors to adjust many active-learning and team-based activities and limit hands-on lab experiences and experimental work. Learning opportunities were also affected, along with in-person interaction among teachers, students, and peers alike. This paper will discuss the transition from in-person to online and hybrid classes and the impact on student learning, engagement, and behavior. The paper will also systematically review the online format's limitations regarding knowledge transfer, learning outcomes, hands-on skills, professionalism, and students' career readiness. Moreover, the paper presents factors that can influence students' academic performance in an online setting, such as stress, anxiety, loneliness, and financial limitations. There will also be a discussion on how instructors can develop assessment methodologies and innovative approaches to teach online effectively.

Keywords

COVID-19 pandemic, Online teaching, human behaviors, empathy, stress, anxiety, feelings of loneliness, low-income students, drop out, assessment methodology, engineering courses, teacher support, communication strategies, engagement, synchronous, asynchronous

Introduction

Two years later, the world is still adapting to an entirely unprecedented situation: the COVID-19 pandemic. The universal impact of the COVID-19 pandemic is the increased isolation felt across the globe and the complete transformation of how people form connections with each other [1]. The restrictions resulting from the pandemic have impacted everyday life, such as work, education, and healthcare. Due to massive shifts in how the world operates, there have been changes in what employers seek and what students pursue. A new emphasis has been placed on teleconferencing, along with many other technological skills.

The conventional education system is still face-to-face for both students and teachers alike. However, COVID-19 disrupted the educational system globally, and traditional face-to-face classroom learning was suspended to prevent the further spread of the virus. Most classes and other scholastic activities were shifted online to continue teaching and learning [2]. This unexpected change shocked many traditional students and faculty since they never willingly opted for it. To replicate the professionalism seen in brick-and-mortar classrooms, educators and

activity sponsors must arm themselves with technology tools to reduce students' stress, anxiety, and feelings of loneliness in today's new teaching and learning environment [3]. This paper reviews the different aspects of teaching and learning during COVID-19.

Shift to Online Learning

The pandemic affects everyone related to education, especially teachers, students, administration, and parents. However, all educational sectors tried to adjust to the new norm of remote teaching swiftly. Educational leadership and management played a vital role in restructuring their university's educational systems keeping in mind the health and safety of faculty, students, and staff in their planning [4]. This included shifting both lectures and laboratory classes to online instruction mode and moving students home. Moreover, COVID-19 has significantly impacted both universities and students in terms of budget reductions and unemployment, and university administrations have to keep in mind longer-term impacts on students' ability to afford a University education.



Figure 1. Depiction of teaching and learning during COVID-19

Engineering education is a combination of theoretical concepts augmented with practical exercises, projects, instruments training, and laboratory activities. In the project-based courses, students learn problem scoping; creativity and idea generation; decision making, incorporating technical, economic, and environmental factors; safety; engineering codes and regulations; and engineering ethics [5]. Students in the labs implement hands-on activities, and cooperation with other classmates prepares engineering students to acquire technical and social skills. A teacher plays a vital role in facilitating learning in an organized manner [6,7].

However, due to the online class format, many teachers can do very little when it comes to having the attention of all students throughout the entirety of class. Many students report shallow engagement during online lectures. If faculty were formally trained on using Learning Management Systems (LMS) properly, this would improve students' experiences. The social disconnect often felt in online classes could be drastically reduced if educators encouraged collaboration instead of exclusively lecturing.

Online learning is more accommodating to many students and allows them to learn at their own pace. In addition to this, the accessibility of online education means that students can learn in moments when they feel ready to learn as opposed to a specific time set by an instructor or institution. However, students have more responsibility for their education in the online format to study the course materials and keep up with the course due dates with a realistic estimation of the time required to complete each task. Online learning serves as a test for students' self-discipline, but there is a tremendous difficulty due to the immense isolation compared to in-person classes [8]. The support gained from in-person learning, from friends and educators, is essential for success and motivation. In online learning, these connections are hindered. Furthermore, students with slower internet may have more trouble in an online format.

The role of parental support for their children at home during the pandemic was a critical aspect. Many students lack a designated space in their home to solely focus on school, so regardless of the educator's effectiveness, many students get distracted easily during online classes. Further limitations of online learning include the inability to test practical skills and a disconnect between teachers and students.

Online Teaching Format

The primary objective of engineering education is to prepare students to solve real-world problems, and the interaction with teachers in lecture theaters and labs is a vital aspect of learning in a face-to-face environment [9]. Learning is further reinforced by campus-focused activities and direct interaction with peers in classrooms, labs, cafeterias, and related extracurricular activities such as clubs, conferences, and competitions. However, based on the internet infrastructure system of education was shifted to online mode utilizing it for the lectures broadcasting, course resources, and as a management platform.

Factors that impact student success in online courses



Figure 2: Depiction of students in an online environment

Three different online teaching formats were utilized to deliver lectures, including asynchronous, synchronous, hybrid, or blended [10]. The asynchronous format provides the teacher and student greater flexibility to record and watch the lecture whenever convenient. The student-teacher communication is via email and online discussion groups. Recording lectures does not allow students to interact with their classmates or connect with the professors, creating a passive learning environment. Synchronous mode is close to the transitional classroom session, since the teacher delivers a live lecture to students online via [Microsoft Teams](#), [Zoom](#), or [WebEx](#) type live streaming platform, offering multi-directional student-teacher interaction and direct communication. A hybrid or blended model combines both asynchronous and synchronous formats without any fixed ratio [11]. This gives students the semi-traditional synchronous learning experience to connect with their classmates while still attending most lectures whenever convenient.

Adapting New Teaching Strategies

A traditional classroom setting is an effective tool for students and teachers alike to interact with one another. Having the skill set to handle different problems requires students to develop a detailed understanding of the concepts and their application to aid in finding solutions. More opportunities to nurture students outside the classroom are done by labs, cafeterias, and related extracurricular activities such as clubs, conferences, and competitions. However, professors and students had to adapt to the challenges brought on by the pandemic, especially for laboratory classes with experiments [12]. Professors needed to create an online teaching environment that allowed active learning and team-based activities considering that students had limited ability to do hands-on lab experiences and experimental work. Students also had to adapt quickly to keep up with classwork and adjust to their new learning environment. Therefore, technology was used to create the environment needed for a professor to teach effectively and for engineering students to learn effectively.

COVID-19 also made professors change certain aspects of their curriculum to deal with unanticipated circumstances. Professors may have felt that they needed to remove or change some elements of labs to help students cope with the situation and still teach the class effectively. However, it may have been challenging to substitute hand-on labs into an online learning format. Many professors also felt disconnected from their students, causing them to not engage with them. They also had to reconsider certain necessary aspects for a student's success that were not possible in an online setting, such as office hours or labs. Many professors could subsidize in-person office hours to online.

The goal for each classroom setting is that students should play an active role in the class and need to be engaged to learn the content for the course better. Professors who want to make an engaging online classroom need to interact with students by using tools available on teleconferencing applications such as talking polls, asking questions, or using the chat box to their advantage to teach their students better. Furthermore, professors can ensure that students understand the concepts through techniques and tools such as discussion boards, video responses, and anonymous polls. Therefore, comprehending where students are struggling to understand certain concepts and addressing those concerns is also an effective teaching tool. Moreover, multiple lab videos to augment the OrCAD and Matlab simulation assignments helped deal with the lab challenge. Moreover, practical lab kits such as Analog Discovery 2, which include many

instruments such as Oscilloscope, Waveform Generator, Power Supply, and Voltmeter, helped many courses and students transform their laptops into electrical engineering workstations at their homes.

Through COVID-19, universities were forced to examine the effectiveness of their online courses. Over the span of the past two years, many institutions have evolved their technological resources to provide students with engaging online classes. Numerous live streaming platforms replicate actual classrooms and provide students the same quality of education online as they would receive in-person. These systems allow educators to simulate regular classroom experiences such as quizzes, discussion boards, and office hours. Furthermore, recognizing the technology advantages and limitations of online classes helps the college's Learning Management System (LMS) prepare classes appropriately for an online setting. Therefore, creating the environment needed for a professor to teach engineering students effectively is also dependent on the LMS and technology.

Student Stress

Students having school-related stress is common in traditional classrooms setting. College students that had a traditional academic career learn ways to cope and be successful in their classes. Furthermore, they learn to balance school with extracurricular activities. However, stress caused by the pandemic was something that most students had not experienced before. Students believed that their education was being delivered ineffectively for certain classes and felt ill-prepared for the assignments and exams. According to the survey conducted by Dr. Emily Hotez, a UCLA Health professor, on undergrads, 93% of those students said they were having trouble coping with pandemic stressors [13]. Other researchers reported similar challenges related to the pandemic in Libya, Latvia, India, and Indonesia [14,15,16,17].

The online setting also did not allow students to meet with their classmates or professors, causing isolation [18]. This made them feel that they could not ask for help from other people for their classes, which decreased their academic performance. The lack of teachers and peers' help has led students to drop out of their courses since they felt they could not keep up or felt supported to a lesser extent by the college.

Another factor that may also inhibit students from success in their classes is the change in their personal lives. All across the United States, people experienced unemployment or decreased income, causing financial strain for many families. This additional stress for students may have caused them to prioritize other aspects of their lives, leading them to spend less time on their academics. Furthermore, since college is a significant financial expense for many students, many drop out to decrease the financial burden on themselves and their families.

Learning Management Systems (LMS) and Students Assessment

Many instructors of the universities were not utilizing the LMS technology and tools necessary for a technology-rich teaching and learning experience of an online class. These include [Canvas LMS](#) that provides technology tools for asynchronous and synchronous learning such as [Canvas Studio](#), [Chat](#), [Discussions](#), and [Web Conferencing](#) [19]. When an LMS is combined with productivity tools such as [Microsoft Office 365](#), educators can promote many interactive

activities utilizing the applications, including [Teams](#), [Sway](#), and [OneNote](#). Moreover, acquiring technology skills from Office 365 students can produce work using the applications mentioned above and make their work more engaging, enhancing their productivity in their professional lives.

Creating an interactive online environment that promotes student participation can be difficult. Discussion boards can significantly enhance classroom interaction. Moreover, adding video assignments where students can put a face to the words can increase the level of comfort, and students are likely to produce better work.

Engineering professors do generally not utilize rubrics for assignments. For online learning, it is critical to know the description of the criterion and the points assigned to each criterion. Moreover, adding feedback by instructors in the comments box for any points deducted from the assignment can significantly help students improve their performance.

Online students assessment while ensuring the ingenuity and evaluating that they have acquired knowledge remained a challenge for both teacher and students. There are several online options to use, including [LockDown Browser – Respondus](#), [SmarterProctoring](#), and [Honorlock](#) [20,21,22]. However, online assessment is not a comfortable experience for many students and hamper their performance.

Financial Burden

The complete overhaul of normalcy by the COVID-19 pandemic has resulted in changes both perceived as positive and negative. However, for many college students, especially low-income college students, the rampant changes have added much stress to their lives. According to a non-profit, ECMC Group, high school student's chances of attending a traditional four-year university decreased from 71% to 53% in only a year [23]. The unexpected costs that come with online learning often add an unprecedented burden to low-income households. For example, high-speed internet is necessary to succeed during virtual learning, and many families cannot maintain the expense, especially alongside other necessary costs [24].

The process of dropping out of school is gradual. No student immediately decides to give up on their plans. However, the persistence of the pandemic has resulted in many students reaching their breaking point [25]. Colleges around the country are fighting to reverse these growing dropout rates; however, there is much uncertainty surrounding the pandemic [26]. Mainly low-income students along with minorities are being forced to dropout of college due to the unsustainable nature of online classes—these groups also have faced the most serious impacts of the pandemic. One of the biggest worries about this growing trend is that an entire generation of low-income students will have lost their chance at a better life [27].

Conclusion

In conclusion, the main objective of this paper is to review the significant changes in education due to the pandemic. The most significant impact of ineffective online classroom formats would be a generation of students ill-prepared for their various fields. If teachers do not work extra hard to ensure students understand the subjects, learners will spend more time learning concepts on their own—the opposite of what effective teaching should be. Moreover, students develop many

social skills in universities, and online instruction can block this development. This means teachers need to prioritize implementing activities that encourage collaboration and creativity, so students do not feel dazed by the monotonous nature of many online lectures. Ultimately, the true success of online learning can be gleaned from two main factors: the competency of graduated students in their respective fields and the social competency students exhibit in adulthood. It can be achieved through proper training of the university faculty to effectively teach online courses that provide the same, if not higher, quality of education as they provide in-person.

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Umar Iqbal

Dr. Iqbal is an Assistant Clinical Professor at Electrical and Computer Engineering, Bagley College of Engineering, Mississippi State University. Dr. Iqbal's research design thinking, engineering education, and mobile multi-sensor systems. He has designed, updated, and taught more than fifteen electrical engineering, engineering design, and technological innovations courses. Professor Iqbal worked in the areas of Multi-Sensor Integration, Navigation Systems, Wearable Technology, Robotics, and Control for industry and academia.

Before joining the Mississippi State University has also served at the University of Ottawa, Queen's University, and Royal Military College of Canada. He received the B.Sc. degree in electrical engineering from the University of Engineering and Technology, Lahore, Punjab, Pakistan, in 1993; the M.Sc. degree from the GIK Institute, Topi, KPK, Pakistan, in 2004; the M.Sc. degree from the Royal Military College (RMC) of Canada, Kingston, ON, Canada, in 2008; and the Ph.D. degree in electrical and computer engineering from Queen's University, Kingston, ON, in 2012.

He has received several prestigious awards, scholarships, and grants, including a \$1.48 million grant from the National Science Foundation (NSF) to improve graduation outcomes for transfer engineering students as Co-PI in 2021. He serves as Academic Editor of Journal of Advanced Transportation, Hindawi Publishing, Associate Editor of the Canadian Journal of Electrical and Computer Engineering (CJECE), IEEE Publishing, and as a Guest Editor of Special Issue of Sensors Journal, MDPI (Multidisciplinary Digital Publishing Institute). He is a senior member of the IEEE 2012 and a Professional Engineer 2016.

Areejah Umar

Areejah Umar graduated from Mississippi State University with her Bachelor's of Science degree in Biological Sciences. Currently, she is working as a scribe in the Emergency Room at Baptist Memorial Hospital Golden Triangle. Her responsibilities include taking notes for medical providers and coordinating with staff members to improve clinical workflow by assisting in result tracking and records retrieval.

She is working on an online teaching techniques research project under Dr. Gómez, Mississippi Gulf Coast Community College (MGCCC), and Dr. Iqbal, Mississippi State University. This research examines crucial aspects of teaching to recommend best practices to design online courses and teaching strategies.

She is also a part-time research assistant job under the supervision of Dr. Noureldin in the Navigation and Instrumentation (NavINST) Research Lab. Her responsibilities include performing experiments, simulations, data analysis, and review articles related to work done in the lab. The main focus of the research is navigation systems that utilize various sensors, data acquisition systems, and simulation software.

Javier Gerardo Gómez

Dr. Javier Gerardo Gómez is a Spanish and Japanese instructor at Mississippi Gulf Coast Community College (MGCCC) and the Instructional Designer (ID) for the School of Language Arts at the Jackson County Campus of MGCCC. Dr. Gómez is a veteran of the United States Army where he served from 1986 to 1989. After his service to the United States military, he attended Central Florida Community College and then the University of Florida where he graduated with honors.

After three years teaching Spanish and French in a 7-12 school in Florida, Dr. Gómez returned to the Department of Defense (DoD) as a Spanish, ESL, and French high school teacher with the Department of Defense Education Activity (DoDEA). While in Japan, Dr. Gómez studied Japanese and was certified by the DoDEA as a Japanese teacher, and began teaching Japanese at Yokota Air Base High School. After fourteen years in Japan, Dr. Gómez returned to Mississippi to pursue his Ph.D. in Instructional Technology and Design (ITD) at The University of Southern Mississippi. His dissertation is titled "Virtual Communities of Practice for Non-Native K-12 Spanish Educators as Professional Development".

While at MGCCC, Dr. Gómez created and taught the first Japanese course for the college and the only one at an MS community college. Additionally, Dr. Gómez has been named Instructor of the Year for the Jackson County Campus (2016), and received the Moody Institute Fellow Award, which helped him return to Japan in the summer of 2017 to continue his studies of the Japanese language and culture.

Most recently, Dr. Gómez completed the seven Quality Matters (QM) workshops that train educators on creating better online courses for all learners.

Muneebah Umar

Muneebah Umar is a freshman Biological Sciences major at Mississippi State University. She is a Presidential Scholar and recipient of the Otilie Schillig Leadership Scholarship. Her research interests include innovative teaching technologies and methods. She has worked with Dr. Iqbal, and Dr. Gomez in identifying methods educators can implement to make online courses effective and beneficial for students. In addition to this, she is a member of Dr. Amirtahà Taebi's lab at Mississippi State University. She is conducting research on noninvasive monitoring of heart activity using noninvasive measurements of heart-induced vibrations on the chest surface.