Implications of COVID-19 on Engineering Education

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Abstract: This research looks towards the ways to provide high-quality engineering education during the COVID-19 era. A total of 118 people, including 30 faculty members and 88 students from engineering departments, took part in surveys and answered quantitative and qualitative questions on the difficulties they encountered while taking online classes at the faculty of engineering during the pandemic period. The research revealed that whereas semi-online asynchronous examinations were related to increased instructors' reported cheating, fully online or open-book/open-note exams were linked with a decrease in instructors' perceived cheating. The findings revealed several obstacles that have a detrimental impact on online engineering education, such as logistical/technical constraints, learning/teaching hurdles, privacy and security concerns, and a lack of appropriate hands-on training. The study's recommendations included implementing practical techniques for many similar institutions around the world, which would aid in the improvement of the learning outcomes of online educations in various engineering subfields. Current research encourages educators to provide more significant assistance with more effective planning and selection of best practices to improve the efficacy of online engineering education during COVID-19 and after the pandemic.

Keywords: COVID-19, Engineering Education, Pandemic, Implementation

I. INTRODUCTION

Engineering education is unprecedented due to the appearance of the COVID-19 pandemic and the resulting response from colleges and universities around the world. In addition to stressors related to the engineering curriculum, many residential college students were asked to relocate away from campus and engage in what, for many students and professors, was a new learning modality: distance learning. At the same time, factor related to the place and social distancing requirements changed and, continue to impact a number of non-academic factors for students, including ability to socialize, ability to engage in relationships, ability to procure ability to exercise and engage in athletics, and ability for students or their providers to remain employed and financially solvent. Finally, as COVID-19, some students have fallen ill, while others faced the prospect of sick family members and deaths in the family.

This paper investigates the incidence implications caused by the pandemic on engineering students' education. The hope is that engineering educators, program administrators, and policy makers can use this data to determine how to best support their diverse student populations both in the immediate future, and during future pandemics, which are expected to occur with increasing frequency.

The Kingdom's government has relied on the distance education system as a modern strategy to encounter consequences of COVID-19 pandemic, and distance education is known as the latest means of education as it uses some technical tools, papers and publications, but without the presence of the teacher with the students in the same place, as the Kingdom has developed distance education by providing some programs Among them distance learning platform and this educational platform

is known as a good alternative to regular education, in order to reach several strategic educational goals, and among those goals is to develop students skills in self-reliance, in addition to saving a lot of time and effort, in addition to facilitating the process of follow-up and knowledge of parents about children's level and performance.

The mean of distance education for engineering student during COVID-19 pandemic in Saudi Arabia requires the role of the student, the teacher, and the guardian to play a role, as the role of the teacher in distance education lies in preparing the appropriate place and following up on all developments on the education platforms, in addition to the importance of searching for new means of good communication with students, while the role of The student organizes the study time, and prepares the appropriate place for distance study, as well as setting rest times between each lesson and another.

II. LITERATURE REVIEW

There are numerous studies conducted on the impact of the Covid-19 crisis implications and the educational achievement for engineering students in terms of grades. Thus, consider the extent to which students adapt to the alternative classroom system and the challenges facing students and faculty members in engineering colleges in general in the Kingdom of Saudi Arabia. The study's primary purpose is to verify the covid-19 effect on Engineering students' outcomes. The study is concerned with comparing engineering students' GPA before and after the Covid-19 crisis, by considering what students prefer and the ability to understand the material and channels used. Moreover, the current study seeks to shed light on the effect of the COVID-19 pandemic on emotional well-being engineering students.

Students Outcome

Engineering student and their courses need access to labs to preform practical experiments. Online education is not yet widespread throughout all engineering disciplines [1]. Online education might not be the best option for good learning and many students prefer to learn hard lectures and courses face-to-face [2,3]. The study carried by Esteban et al 2020 to determine the impact of COVID-19 on student experiences and expectations. The finding of their study showed that student academic outcomes because of COVID-19 have directed some large many higher education students to delay their graduation (13%), others who withdraw from classes (11%) and seeking to change majors (12%). Also, around 50% of the study sample reported separately a reduction in study hours and their academic accomplishment [4]. Some studies specified that self-regulated learning (SRL) greatly affected students' academic outcomes and learning implementation [5]. Researchers specified that SRL students with strongly developed skills were more likely to prosper both in classrooms and online learning. These studies and the development of good tools for evaluating and self-evaluating learners have become especially necessary in the COVID-19 pandemic to guarantee good performance in e-learning environments [6-7].

A study was conducted to verify the effect of the COVID-19 pandemic on higher education, study was carried out on approximately 1500 students from large American universities utilizing a convenient instrument that designed to recover the causal effect of the pandemic on students' current and outcomes that are expected. The findings revealed that large negative impacts across many dimensions. As a result of COVID-19: 13% of student's overdue graduation, 40% have missed a job, internship, or job offer, and 29% expect to earn less at age 35. Besides, these impacts have been highly variable. One-quarter of students increased their study time by more than 4 hours per week

due to COVID-19, while another quarter decreased their study time by more than 5 hours per week. This heterogeneity often followed existing socioeconomic divides [4]. According to Archidiaconal [8], higher education students were asked their current GPA in a post-COVID-19 world and their expected GPA in the lack of COVID-19, we can back out the subjective treatment effect of COVID-19 on academic performance.

Students Psychological and Emotional Well-being

The COVID-19 pandemic has heavily influenced the emotional wellbeing and mental health of people around the world [9]. many of students have experienced unbearable psychological pressure, especially due to the pandemic's impacts on daily life, the economic effects, and the delays in academic life [10]. 35% of Chinese people has psychological problem in the COVID-19 epidemic [11]. Previous studies show that the psychological symptoms such as stress, depression, anxiety, and insomnia will increase between people in quarantine due to long period of quarantine, boredom, fears of infection, etc... compared to people not in quarantine or in the general population [8]. A previous study in 194 cities in China has shown that more than 50% of the 1210 respondents from the general population reported moderate to severe levels of psychological difficulties due to the COVID-19 outbreak with about 16% suffering from symptoms of depression, 29% from anxiety, and 8% from stress [12]. Out of 7143 college students in China about 24.9% students have experienced anxiety because of COVID-19 outbreak, the study also found that students were one of the groups experiencing a higher point of psychological difficulty [13]. A decrease of social interlinkage, as is probably to be caused by the pandemic and social distance measures, can prompt lower psychological wellness [14]. A strange condition known as "headline stress disorder" can be seen during present day pandemics, it is described by high passionate reaction, as stress and tension, to unlimited reports from the news media, that may cause actual manifestations including palpitation and sleep deprivation [15]. In quarantine during Ebola outbreak, research confirmed the same previous findings which is the people reported fear, anger and anxiety-induced insomnia [16,17].

Virtual Classes

Most universities around the world have transferred virtual classes during the COVID-19 pandemic. According to UNESCO studies, the COVID-19 epidemic constituted a quantum jump over in enriching scientific cooperation and creating alternative means in virtual educational processes. The organization supported developing distance learning through virtual classroom systems due to the closure of educational institutions due to the Corona pandemic [19]. A previous research among 156 students who took either an online or face-to-face learning has explored that there is no significant difference in learning preference between face-to-face and virtual instruction [20].

Another research among medical students from Saudi Arabia uncovered that the web-based educating is a generally welcomed methodology that has numerous favorable circumstances including a better students' performance and time saving [21].

A study among Dental students at Harvard School uncovered that the switch to online learning has deteriorated their learning with expanded pressure, diminished commitment, and a similar insight level of class participation [22]. Based on a study with a total of 488 students in dental and medical college, majority of students (67%) liked in up close and personal learning over virtual learning. In any case, just 32% of students favored virtual learning [23]. Educators at the National Institute of Science and Technology of Toulouse, France conceded that they studied virtual learning in two months of COVID-19 pandemic than in the ten years earlier [24]. Anyway, Virtual learning has both

positive and negative impacts.

One reason that previous studies concern about the lockdown of educational institutions may not be a typical proceeding for learning loss as the result of COVID-19 is that the distance education approach happened in many educational institutions since of COVID-19 outbreak in 2020 [25]. This internet teaching could alleviate the damages that students' involvement in throughout the pandemic. On the other hand, there is also evidence suggesting that measures undertaken by educational institutions may not have been as effective as hoped [26]. With the above objectives in mind, the current review was designed to summarize the existing literature addressing to students outcomes, mental health concerns and emotional well-being related to the COVID-19 pandemic.

The interaction between coronavirus diseases and movement of people are fundamental to understanding health, security, and global change. The main reasons for the increasing pandemic threat within the 21st century is a rapidly growing and mobile world population; urbanization trends and therefore the concentration of people; industrialized food production [27]. The challenge is now to collectively learn from this global tragedy to accelerate the transformation of sustainable tourism [28]. The COVID-19 pandemic has greatly affected the tutorial sector [29]. There is a robust possibility of deteriorating psychological state due to the resulting sense of uncertainty and anxiety among students and school members [30]. Technology-based strategies are being adopted by teachers and academic institutions to supply education [31]. With increased access to technology, it had been important to require substantial measures to make sure data privacy and security. Alongside addressing educational challenges, it had been pertinent to deal with the psycho-social challenges of scholars during the quarantine. Before rolling out the digital tool, students, teachers, and administrators in schools must be trained about its usage, and most significantly, to assess students learning there must be some strategies to guide and monitor their learning [32].

Dhawan [33] presented in his comprehensive study, has summarized the alternative teaching methods adopted by higher education institutions during the COVID-19 epidemic, by explaining the strengths, weaknesses, challenges and weaknesses of this type of learning methods.

Almaiah et al [34] carried study which focused on conducting interviews for a sample of IT students and experts from six Jordanian and Saudi universities. The purpose of these interviews was to identify the challenges facing the methods of success of the online learning system during the Covid epidemic by developing instructions and recommendations to enhance the effectiveness of the virtual education system on the part of students and faculty members.

III.   RESEARCH METHODOLOGY

Present study surveyed engineering students and professors from several universities in the Kingdom of Saudi Arabia that utilized method of a quantitative component. The applied quantitative component based on a self-administered questionnaire adapted from previous study tool was used to collect data from students and professors of faculty of engineering universities in the Kingdom of Saudi Arabia in order to reach conclusions that contribute to providing directions for improving and developing reality and revealing the relationship between these variables (Creswell, 2007).The literature related to the subject of the study was also collected from both primary and secondary sources including books, articles and previous studies to prepare the theoretical side of the research. Ethical approval for the study was provided by leading department of engineering faculty of king Abdulaziz University in Jeddah. Written informed consent was collected from all participants prior to data collection. As for data collection and statistical analysis, a special questionnaire was designed

for this purpose. The questionnaire was designed according to Likert scale, with the answers (strongly disagree, disagree, don't know, agree, strongly agree,), given the weights [1, 2, 3, 4, 5]. The higher the mean, indicates to higher degree of consent on the clause.

In this study, the researcher used questionnaire as suitable approach of quantitative data for the study participants. The questionnaire composed of several parts including sections concerning engineering students and professors implication on COVID-19 in engineering education demographic information of both participants of the study. Each section divided into some subsections entirely.

The population of this study is 250 individuals. Still, some apologized and others who responded to the questions according to the available circumstances. The request was optional for the participating students or academic staff members. A total of 118 individuals have actually participated in the study. The questionnaire distributed to all participants including students and professors. Furthermore factor analysis and regression analysis were done for accurate results.

IV. RESULTS

In this part the researcher used descriptive statistics as frequency and percentage to describe the sample according to their demographic characteristics. Figure 1 shows majority of professors 76.7% are male, while the rest 23.3% are female. Likewise, the majority of students 71.6% are male, and the rest 28.4% are female. The following bar-chart shows these percentages.
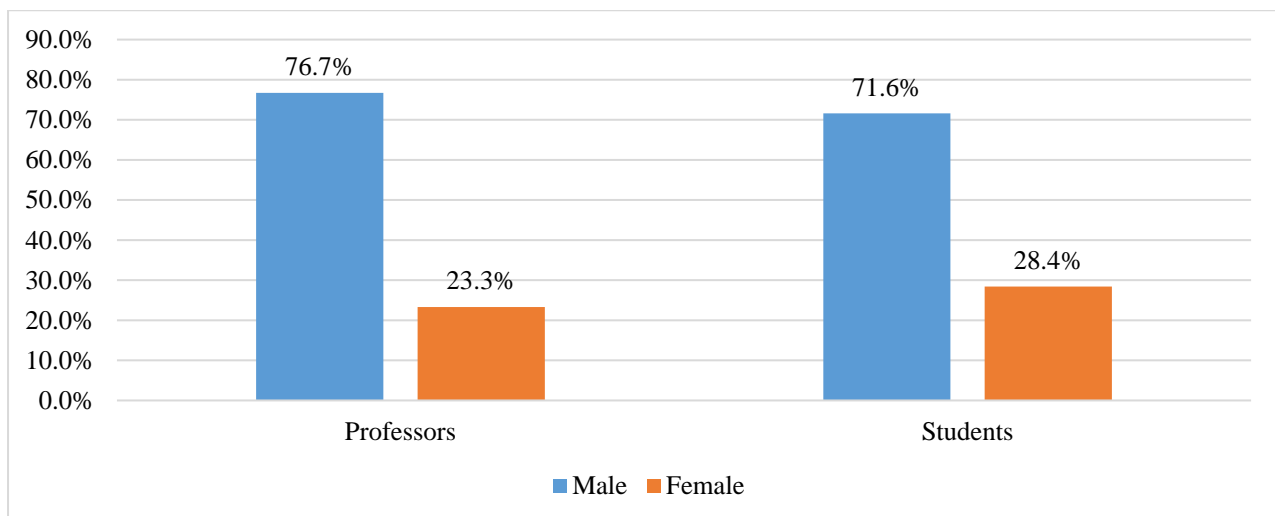

Figure (1) Frequency Distribution of Participants according to Gender

Here 26.7% of the professors are from King Abdul-Aziz University, 13.3% are from Jeddah University and 13.3% from King Faisal University, 10% from Taif University, 10% from University of Tabouk, and the rest of professors from University of Business & Technology, Umm Al Qura University, King Fahad University of Petroleum and Minerals, King Khaled University, Qassim University, and other universities with 3.3% for each. Regarding students, it is found that 39.8% of students from King Abdulaziz University, 35.2% from Taif University, 10.2% from Umm Al Qura University, 2.3% from King Saud University, while the rest from King Khaled University, University of Tabuk, Princess Nourah Bint Abdulrahman University, Yanbu Industrial College, and other universities with 1.1% for each. 66.7% of the professors in industrial engineering program, 13.3% in architectural engineering program, 6.7% in electrical engineering, 6.7% in mining engineering program, and rest of professors in other engineering programs (mechanical and

software). Regarding students, it is found that 25% from students in industrial engineering program, 21.6% in electrical engineering program, 15.9% in architectural engineering program, 13.6% in Mechanical engineering program, 6.8% in Software engineering program, and the rest of students in other engineering programs. 64.8% of the students are undergraduate level, while the rest 35.2% of students in graduate level.

Table 1. Implications on Academic professors academic skills by COVID-19

Statements	Mean	S.D	Agreement level	Rank
9. Lack of industrial visits negatively affected my ability to explain industrial problems	3.80	0.96	Agree	1
10. Virtual teaching negatively affected my ability to explain concepts of Science and Mathematics	3.60	1.25	Agree	4
11. Negatively affected my ability to provide alternate solutions in Engineering projects	3.57	1.22	Agree	5
12. Negatively affected my ability to create teamwork among Engineering students	3.70	1.18	Agree	2
13. Negatively affected my ability to meet deadlines due to online classes	3.20	1.24	Neither agree nor disagree	6
14. Negatively affected my ability to use engineering tools, techniques and skills	3.70	1.24	Agree	2
Overall	3.59	1.18	Agree	

Table 1 shows the means and standard deviations for each statement in the third dimension in professors questionnaire; COVID-19 on Academic professors academic skills. The overall mean of the dimension is (3.59) which lays within the second interval (3.40 –< 4.20) of Likert Five-Level Scale, and this indicates that the general opinion of professors tends to the level of response (agree), i.e. the majority of professors agree that COVID-19 has implications on Academic professors academic skills. According to the mean values, the statements had been ranked in descending order from the highest mean to the lowest, so, the statement (Lack of industrial visits negatively affected my ability to explain industrial problems) came in the first order with mean (3.80) and level of response (Agree), then the statements (Negatively affected my ability to create teamwork among Engineering students) and (Negatively affected my ability to use engineering tools, techniques and skills) came in the second order with mean (3.70) and level of response (Agree), then the statement (Virtual teaching negatively affected my ability to explain concepts of Science and Mathematics) came in the fourth order with mean (3.60) and level of response (Agree), then the statement (Negatively affected my ability to provide alternate solutions in Engineering projects) came in the fifth order with mean (3.57) and level of response (Agree). The statement (Negatively affected my ability to meet deadlines due to online classes) came in the sixth order with mean (3.20) and level of response (Neither agree nor disagree).

Factor analysis

Researchers conduct factor analysis to achieve various objectives. One of these objectives is to distribute the items of the questionnaire into certain scales (dimensions), and to see how each factor extracted explains the variations. Another objective is to check for sampling adequacy, in addition to that is to use the extracted main factors that can be used in further analysis. In this current study,

there are two questionnaires, one is addressed to the academic staff, and the other to the university students, and each questionnaire contains 14 items distributed among 3 factors. The first factor aims to measure the Covid-19 pandemic implication on academic staff and students; the second factor is to measure the impact of Covid-19 on mental health and emotions of both academic and students, while the third factor is to measure the influence of Covid-19 on academic and students' skills. These variations measured by each factor extracted shown in table 2 below:

Table 2. The total variance explained by each factor.

Total Variance Explained								
	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.727	40.907	40.907	5.727	40.907	40.907	3.433	24.521	24.521
2	2.614	18.671	59.578	2.614	18.671	59.578	3.093	22.089	46.610
3	1.334	9.531	69.108	1.334	9.531	69.108	2.758	19.697	66.307
4	1.221	8.724	77.832	1.221	8.724	77.832	1.613	11.525	77.832
5	.925	6.607	84.439						
6	.769	5.495	89.934						
7	.534	3.818	93.752						
8	.450	3.212	96.964						
9	.209	1.493	98.457						
10	.126	.901	99.359						
11	.042	.301	99.660						
12	.035	.253	99.913						
13	.010	.073	99.985						
14	.002	.015	100.000						
Extraction Method: Principal Component Analysis.									

The results in table 2, revealed that, there are 4 factors extracted with initial Eigenvalues greater than one. The 4 factors explained about 77.832% of the variance. Meaning that, the 4 factors can include or explain 77.8% of the questionnaire items. It is clear that, the first factor includes about 40.91% of the items, while the second factor explains 18.7%, whereas the third factor explains 9.5%, and factor four explains 8.7%.

Factor analysis of students questionnaire:

Running the factor analysis to the students questionnaire concludes with the following results that illustrated in the table 3.

Table 3. Total variance explained.

	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	6.140	43.856	43.856	6.140	43.856	43.856	3.464	24.741	24.741
2	1.353	9.662	53.517	1.353	9.662	53.517	2.756	19.686	44.427
3	1.263	9.021	62.539	1.263	9.021	62.539	2.536	18.112	62.539
4	.990	7.074	69.612						
5	.824	5.883	75.496						
6	.645	4.609	80.104						
7	.571	4.076	84.181						
8	.494	3.531	87.712						
9	.423	3.022	90.734						
10	.334	2.387	93.121						
11	.306	2.184	95.305						
12	.263	1.877	97.182						
13	.229	1.635	98.817						
14	.166	1.183	100.000						
Extraction Method: Principal Component Analysis.									

Total Variance Explained

The results in table 3 shows the total variance explained in factor analysis. The results reveal there 3 main factors extracted that explain about 62.539% of the variance. This indicates that, the 3 factors explained about 62.539% of the items in the questionnaire. The results show that, factor 1 is the most important strong factor which explains 43.856% of the loadings of the items, while factor two explains 9.662% of the loadings, whereas factor 3 explains 9.021% of the loadings.

Table 4. The Rotated Component Matrix

Rotated Component Matrix[a]

	Component		
	1	2	3
q11	.792		
q12	.790		
q4	.711	.321	
q10	.538	.364	
q14	.516	.412	.510
q13	.479	.416	.446
q1		.759	

q5	.361	.745	
q2		.596	.457
q6	.409	.515	.311
q3	.457	.499	.317
q7			.903
q8	.318	.324	.602
q9	.451		.581
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.			
a. Rotation converged in 5 iterations.			

Table 4 presents results of rotation using Varimax method, show the items loadings on the 3 factors extracted in the factor analysis. The results reveal that, items number (4,10,11,12,13 and 14) are loaded highly on the first factor. Whereas the items numbers (1,2, 3, 5, 6) are loaded highly on factor two. The items numbers (7,8, 9) loaded highly on factor three.

Results of regression analysis:

The main purpose of simple regression analysis is to examine the influence of participants' implications about the Covid-19 Pandemic on their mental health, emotions, and skills.

Table 5. Regression analysis examining the impact of COVID-19 on academic professors skills.

Model	Coefficients	Beta	T-test	P-value	F	Sig.
Constant	-0.338		-0.097	0.92	40.745**	0.00
Implication of Covid-19	0.936	0.77	6.38**	0.00		
R = 0.770		$R^2 = 0.593$,		Adj.R^2 = 0.578		

**indicated that F-statistics, is significant at the (0.01) level
**Indicated that, T-test statistics is significant at the (0.01) level.

Table 5 shows the value of F-statistics is statistically significant at the (0.01) level, indicating that the simple regression model is efficient in estimating the variation in academic professors skills. In addition, the results reveal that, the coefficient of determination (R2) is reaching (0.593), which indicates that, the regression model effectively interprets the variations on the academic staff' skills by 59.3%, if other factors influencing the skills remain equal. Furthermore, the results show that, the beta value of the independent variable (implication of Covid-19) is equal to (0.77), while T-test statistics is statistically significant at the (0.01) level. This result confirmed that, there is a significant and positive effect of the academic staff implications of Covid-19 on their skills.

Summary of Results

Through the analysis, it was found that there is a discrepancy and agreement among the participants in the answers to the questionnaire that was prepared for students of engineering faculties from various universities and in which the departments of the Faculty of Engineering participated, in order

to know the impact of the COVID-19 on the performance and achievement of students of faculties of engineering exclusively, and the challenges that faced both students and faculty members. Through the responses, it became clear the significant impact that COVID-19 had on engineering colleges, until those colleges forced them to resort to alternative online education methods, despite the pros and cons they face. The most important challenges facing students are shown in the technical difficulties if both students and faculty members find access to the sites and the material costs and efforts compared to the traditional education system.

There is a need to provide mechanisms and equipment in addition to training students and faculty members to use alternative programs and provide factors that help strengthen the dual education system in engineering colleges during the Covid period. Following are the findings of the present study in the summarized form:

1- The majority of professors agree to the implications of Academic Professors by COVID-19.
2- The majority of professors agree that COVID-19 has implications on Academic professors mental health and emotions.
3- The majority of professors agree that COVID-19 has implications on Academic professors academic skills.
4- The majority of students agree to the implications of COVID-19 on students' academic achievements and performance.
5- The majority of students agree to the implications of COVID-19 on students' mental health and emotions.
6- The majority of students agree to the implications of COVID-19 on Engineering students' academic skills.
7- There is a statistically significant difference between professors and students in their opinion toward the Implication of COVID-19 on Academic.
8- There are no significant differences between professors and students in their opinion toward Implication on mental health and emotions and the Implication on academic skills.
9- There are no significant differences between male and female professors in their opinion toward the implication of COVID-19.
10- There are no significant differences between male and female students in their opinion toward (Implication on academic achievements and performance) and (Implication on academic skills).
11- There is a statistically significant difference between male and female students in their opinion toward the implication of COVID-19 on mental health and emotions – for favor of female students with the higher mean value.
12- There are no significant differences between undergraduate and graduate students in their opinion toward (Implication on academic achievements and performance) and (Implication on academic skills).
13- There is a statistically significant difference between undergraduate and graduate students in their opinion toward the implication of COVID-19 on mental health and emotions – for favor of undergraduate students with the higher mean value.

V. DISCUSSION

The paper has identified and proposed relevant interventions to improve the online delivery of engineering courses during pandemic. According to the results, there is a statistically significant difference between professors and students in their opinion toward the Implication of COVID-19 on Academic. Thus also there are no significant differences between professors and students in their opinion toward Implication on mental health and emotions and the Implication on academic skills.

With COVID-19 and the abrupt transition to online instruction, access to reliable internet connection and personal computer or tablet have become the main factors affecting students' learning outcomes. The study results showed that engineering students did not have proper access to reliable internet connection, triggering a concern about widening of the digital equity gap among students due to COVID-19 pandemic. To address this problem, the faculty can provide WiFi access on campus's open areas and well-ventilated buildings while monitoring for social distancing and sanitizing the surfaces frequently. For those needing computing devices, a loaner program can be implemented where students can borrow laptops for a certain period to access the course materials and complete the course requirements. The faculty can also afford a virtual desktop environment for students to access all necessary software. Using free scanning applications on smartphones or tablets can address the lack of access to scanners.

These results are consistent with those reported in a recent study conducted at a Hispanic-serving institution's Biomedical and Chemical Engineering departments [35]. While the percentage of our students who had issues with lack of motivation or private space seemed to be higher, both studies highlight the necessity of providing more socio-emotional support for students during the difficult times of pandemic.

Pandemic has caused educational loss, delayed graduations, cancelled internships and lost job offers. The new generation of students away from face-to-face instruction may lack certain learning experiences. For example, there might be a generation of engineering students who performed most of their lab activities virtually and thus lack true hands-on skills.

To reduce the educational gap, universities could develop and implement diagnostic tools to learn where and how large the deficiencies are. Based on the acquired knowledge, they. As the pandemic progresses, the flexibility of university policies could also help narrow the educational gap, especially for students with lower socioeconomic status. Allowing students to adjust their course load, timing of assignments and tuition payment schedule would enable them to make reactive decisions to mitigate the educational loss[36]. A need for further research on this top is undeniable.

Educational Institutions quality standards related to online education is of paramount importance in online education. Effective communication is key in bridging the divide and reconciling administrator and faculty for an enhanced online education[37]. A considerable number of our faculty reported lack of access to hardware, software and necessary tools for online instruction.

The study revealed that although the majority of undergraduate Management students required more time and effort to prepare for the online exams (compared to the traditional ones), they regarded the clarity and prompt grading and feedback features of the online exams substantially advantageous[38]. This study investigated the challenges of engineering online education during the pandemic, and a global emergency occurred. As the pandemic continues and various academic stakeholders explore new strategies to better adjust to the new *normal*, subsequent studies conducted soon might provide a more accurate picture of the online engineering education.

For surveys to all faculty and engineering students using different means shows low response rate of the students might have introduced some participation bias to the results.

Further studies need to be carried to address race, gender and socioeconomics demographics to investigate the magnitude of educational challenges that underrepresented groups experienced during the pandemic compared with other groups. Considering some institutional data such as grades,

faculty and student perception of learning, financial aid requests from both pre- and during pandemic would also enhance the study.

Strategic Framework:

The proposed strategic framework is summarized as follows:

First: Strategies for institution/engineering administration
- To afford budget allocation to provide basic equipment for the online instruction to both faculty and students in need.
- To create a virtual desktop environment and to enable faculty and students to access necessary software.
- To provide training workshops for faculty members and students to further familiarize with online teaching and learning technology and tools.
- To provide a syllabus template for online courses including all the important information needed for ABET accreditation.
- To develop and organize systematic repository of resources pertinent to engineering online instruction.

Second: Strategies for engineering faculty:
- To break down a long lecture into shorter segments with more frequent breaks
- To encourage group discussion or problem-solving activities among students such as Zoom breakout rooms.
- Being available during the exams on Zoom to answer students questions.
- To provide students with a clear roadmap and instruction for the online course
- To make the recordings of the live lectures available after the lecture.
- To administer practice exams for students
- To use an open-book/open-note and synchronous assessment methods that support academic integrity.
- To avoid utilizing camera/microphone to proctor exams.

Third: Strategies for engineering students:
- To use free scanning applications on their smartphones.

VI. CONCLUSIONS

The COVID-19 pandemic brought real challenges to face in engineering education. At the same time, it provided opportunities to adapt the way of interaction and education delivery.

This paper aims to identify challenges encountered online instructions of engineering courses during COVID-19 pandemic by surveying students and faculty at our minority-serving institution. Various logistical, technical and learning and teaching problems has been identified, and several interventions were proposed to address them. The results of this study add to the developing body of knowledge about the effect of pandemic on engineering education. This study also provides empirical evidence for the proposed strategies to enhance the online engineering education during and post-pandemic. Future work will be necessary to include a thorough study on assessing the efficacy and sustainability of each proposed intervention**.**

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Ethical statement: We declare that they have followed ethical responsibilities.

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