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Online Mode of Teaching and Learning Process in Engineering Discipline: Teacher Perspective on Challenges Faced and Recommendations

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Abstract: The COVID-19 pandemic has affected people from almost every walk of life in general and academia in particular. It had a huge impact on teaching and learning resulting in a sudden shift from classroom and face-to-face teaching to distance and online teaching and learning. This sudden shift created a lot of ruckuses in the teaching of engineering disciplines. This study is pertinent to the examination of faculty perceptions of online teaching in Pakistani universities and the obstacles they face in teaching engineering students through the online mode during this pandemic. The research takes a quantitative and sample survey approach. A Google form questionnaire was used to collect the data from a sample of 91 faculty members from the engineering discipline of different universities in Pakistan during 2022. According to the study's findings, faculty generally have a favorable opinion of virtual teaching in the context of COVID-19 for closing the achievement gap and guiding students' futures in difficult times. However, they ran into a number of challenges when teaching online, including technological difficulties, problems with student participation, challenges with online tests and assessments, etc. The results of this study will urge educational institutions and policymakers to use the most up-to-date instructional methodologies and offer teachers ongoing professional development in order to improve the quality of online teaching, learning, and assessment in universities. Previous studies discussed a number of obstacles faced by students in virtual teaching in higher education, overlooking the perception and challenges faced by the engineering faculty. The present study replenishes this gap.

Keywords: online teaching; COVID-19; teaching challenges; engineering education; perception; ICT devices

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1. Introduction

The novel coronavirus (Coronavirus disease 2019 [COVID-19]) pandemic was reported in China in December 2019, and the World Health Organization (WHO) declared it a worldwide pandemic on 11 March 2020 [1,2]. Almost every country has suffered at the hands of this virus, with India, Korea, Germany, Italy, Singapore, Brazil, the USA, and the UK taking the lead as these countries had a very high number of cases [3]. This outbreak resulted in an unprecedented closure of the world in a very short span of time, thus affecting almost every field of life. The education sector was no exception, as schools, colleges, and universities were closed for long periods of time in most parts of the world and educational institutions are still conscious in this regard [4]. This sort of disruption in academic activities could not be afforded for too long [5] and forced academia to move to online teaching to respond to the need to continue teaching and learning and minimize the damage.

Pakistan is the fifth largest country in the world in terms of population, and the academia here also suffered badly due to disruption in face-to-face (F2F) teaching due to lockdowns. Although virtual teaching has been offered in some universities of Pakistan, such as Allama Iqbal Open University and Virtual University, it had not been a common mode of teaching in the past. Under the prevailing circumstances, online teaching has emerged as the only available remedy to overcome the continuous learning loss due to a highly infectious virus. The Higher Education Commission (HEC) of Pakistan, therefore, directed universities across the country to reopen their doors to students by using learning management systems (LMS) and other internet tools such as Zoom, Microsoft Teams, and Google Meet. The Pakistan Engineering Council (PEC), the country's governing organization for engineering education, developed policy recommendations for online learning, recommending online learning for the cognitive domain and simulations for psychomotor learning through e-labs based on Bloom's taxonomy [6]. After the reopening of engineering institutes, students were asked to attend physical labs to make up for the lab education that could not be provided online [7].

F2F learning has been a method largely used for the transfer of knowledge, the synchronous instruction method where contents are delivered to the students in person, who can interact with fellow students, as well as the instructor [8,9]. In contrast to this approach, lectures can also be delivered virtually, i.e., not F2F. These lectures may be synchronous (delivered to the students in real-time) or asynchronous (recorded lectures are available online) [8–13].

1.1. Review of Online Teaching during COVID-19

Online instructions offered both advantages and disadvantages for teachers and students. On the positive side, online classes do not require students and teachers to be present at a common location, and they can attend lectures from anywhere. This eventually saves traveling costs to the university, time to commute to and from campus, and maintenance required for the lecture rooms [14]. The availability of recorded lectures offers flexibility as students can view them at their own convenience and at their own pace [9,15,16]. This flexibility of planning their own schedule to suit their abilities may help them to achieve better work–life balance and a more personalized study program [17]. In addition, proceeding with the teaching material at their own pace does not put the students under unnecessary pressure of matching the pace of the teacher or other students.

On the negative side of the sudden shift to the online mode of teaching, faculty teaching to tertiary level students encountered several challenges, such as technical obstacles, issues of student engagement, and difficulties in online assessments, etc. [18,19]. Although the technology was used to overcome these challenges, technology alone does not guarantee success. Teachers who are not digital citizens struggled with adopting new technologies and had to go the extra mile to achieve competency and deliver the content online effectively [19,20]. They had to learn techniques such as polls and online quizzes to make their lectures interactive and engage the students as much as possible [21–23]. The university faculty has indicated a considerable desire for more elaborative coaching for digital teachings, such as designing and delivering online courses, assessing students' learning, and virtual classroom management [19,21,24].

The lack of active engagement of students during the online learning process is one of the major challenges faced by most of the faculty, which can largely be attributed to distractions and a lack of monitoring during the lecture [25,26]. Students who are addicted to internet gaming may be physically present during online sessions while playing games on their mobile devices and it is nearly impossible to monitor their behaviors remotely [27]. In online delivery, the elements influencing students' learning interests, learning behaviors, interactions, classroom etiquette, participation, and conversation are also absent [28]. Evaluating student performance was even more challenging, as it became almost impossible to check whether students take the examination without external help [19,29,30]. It is also vulnerable to plagiarism, cheating, proxy, and copy–pasting [31,32]. Researchers such as [33] have also raised questions about the authenticity of the online assessment and, therefore, opined that considerable changes to the grading system should be made, as it is unimaginable to claim that learners were receiving the same learning experiences through online learning during this pandemic.

Engineering education is a peculiar field of higher education, where experiments during laboratory sessions are a crucial component of an undergraduate engineering program [34]. Due to the restrictions during COVID-19, these important components, such as laboratories and related equipment, were unavailable. Therefore, they had to revert to alternate methods of teaching and learning to avoid this loss of important aspects of engineering education [34,35]. Engineering universities were under enormous financial stress, as they had to invest on top of what they had spent on arranging the infrastructure for facilitating the F2F traditional lecture, and had to make investments in the form of license fees for software tools, as well as digital gear required for online teaching and labs [36,37].

1.2. Challenges Faced by Faculty in Pakistan during COVID-19

A number of researchers have explored the challenges faced by academia in Pakistan during COVID-19. The study conducted in [38] found that faculty in general have a positive perception of online teaching, citing accessibility and flexibility as major benefits, but a significant part was of the view that this transformation was not straightforward. The main challenges include a lack of knowledge of ICT, content production, F2F interaction with students, and student engagement, as well as difficulties in assessing student learning [5,38,39]. The findings of the study in [39] supplemented the above challenges with lack of ownership, lack of administrative support, and load-shedding of electricity, which mostly impede online teaching in Pakistan's universities. The study conducted in [40] provided guidelines, especially for online assessment. The findings also revealed that teachers lack knowledge about the norms of online delivery of courses [38,40]. The other challenges reported by faculty during the online mode of education include lack of institutional support, poor LMS, internet connectivity issues, maintaining student engagement, and problems with understanding the unique dynamics of online education [19,28,39]. Almost all studies recommended capacity-building programs related to online teaching tools and instructional design methodologies.

1.3. Purpose of the Study

In the midst of the COVID-19 pandemic, engineering universities in Pakistan have shifted their physical classes to online classes with insufficient resources and experience of online teaching. The transformation and challenges faced by the engineering faculty during the COVID-19 pandemic are examined in this study. Specifically, the objectives of this research were as follows:

1. To examine the challenges faced by the engineering faculty while teaching through the online mode of instruction during COVID-19.
2. To examine the difference in the perceptions of faculty members about the challenges faced by lab instructors while teaching through the online mode of instruction during COVID-19.
3. To share the lessons learned with a view to enhancing and improving the online delivery of engineering subjects.

2. Methods

This research examined the perceptions of university teachers and instructors when teaching online.

2.1. Study Design

This study is descriptive in nature and used a survey research design to examine the status of the transformation from the traditional to the online mode of teaching in the engineering discipline of selected universities of Pakistan during the COVID-19 crisis, along with the challenges faced by teachers in this mode, as perceived by faculty members and instructors. Before taking part in the study, informed consent was sought from all individuals.

2.2. Research Subjects

Participants from the engineering departments of the seven campuses of the COMSATS University Islamabad (CUI) located across Pakistan (Lahore, Islamabad, Wah, Abbottabad, Sahiwal, Vehari, and Attock), as well as eight other universities from the metropolitan city of Lahore, were invited. The virtual campus of CUI was not included as it uses the online mode of teaching and did not see much deviation. The seven campuses of CUI are located at different geographical locations across the country, including one in the capital and some others located in not-so-developed areas. Students from all over the country attend these universities with varied levels of facilities. For example, many students from the northern areas of Pakistan attend the CUI campus located in the capital of Pakistan, which has limited access to broadband internet connections. Similarly, Lahore has the best government and private engineering universities, which attract students from all across Punjab, the main province that constitutes 60% of Pakistan's population. All the participants had no significant experience with online teaching as this mode of teaching had not been offered by their respective universities. However, faculty members have familiarity with learning management systems (LMS) with dedicated accounts to these systems.

All of the faculty members of the Department of Electrical and Computer Engineering of fifteen different campuses were selected as a population. Using the census technique, all members of the population were also selected as samples. They received an invitation to participate in the study via the department mailing list, along with a participation information sheet. By filling out a consent form and returning it to the researchers, the participants gave their consent to participate in the study. All faculty members who gave their consent to participate in the study were contacted. Finally, 91 faculty members, including lab engineers, took part in the study. The participants were also given the right to withdraw from the study even after giving their consent. The demographic information of the participants (i.e., gender and designation) is provided in Table 1.

Table 1. Participant demographics.

Characteristics	Attributes					Total
Participant Gender	Male			Female		91
	76.9%			23.1%		100%
Participant Age (Years)	30 and less 8.8%	31–35 29.7%	36–40 26.4%	41–50 26.4%	51 and above 8.8%	91 100%
Designation	Professor	Associate Professor	Assistant Professor	Lecturer	Lab Engineer/ Instructor	91
	5.5%	14.3%	27.5%	43.9%	8.8%	100%

2.3. Instrument

A short questionnaire comprising three parts was designed as a research instrument to collect the data. The first part was designed to seek the demographic information of the participants. The second part used a five-point scale, ranging from strongly disagree (SD) to strongly agree (SA) to capture the opinions of participants on sixteen statements. Six questions in the questionnaire were designed to obtain the opinions of faculty members about the provision of resources, four questions about the delivery of content (teaching), two about students' assessment, three questions were about examining the level of students' interaction and engagement, and four about examining the level of workload and effort needed on the part of faculty. The reliability of the questionnaire was calculated using Cronbach's Alpha (CA), which was found to be 0.835, and thus, highly reliable. The CA was also calculated for all five factors of the questionnaire, 0.753, 0.695, 0.821, 0.863, and

0.698, respectively, indicating high reliability. The third part of the questionnaire comprised open-ended questions. The items of the questionnaire are given in Table 2.

Table 2. Survey questions.

Sr. #	Questions
	Questions related to the provision of resources
Question 1	I was satisfied with IT support provided for the online mode of education.
Question 2	I was satisfied with the digital hardware provided for the online mode of education.
Question 3	I was satisfied with the quality of internet facilities during online mode of education.
	Questions related to teaching (delivery of content)
Question 4	I had prior knowledge of using ICT devices for online modes of education.
Question 5	I was satisfied with the online delivery of the lectures as compared to the face-to-face delivery.
Question 6	I did not face any problems while delivering lectures from home.
Question 7	I was satisfied with the conduction of lab experiments during the online mode of education.
	Questions related to assessing students' performance
Question 8	I was satisfied with the standard of assessments during the online mode of education.
Question 9	I was satisfied with the maintained integrity of assessments during online mode of education.
	Questions related to interaction and engagement
Question 10	I was satisfied with the student teacher interaction during online mode of education.
Question 11	I was satisfied with the student-student interaction during the online mode of education.
Question 12	I was satisfied with the engagement of students during online mode of education.
	Questions related to workload and effort
Question 13	The faculty workload increased during COVID-19.
Question 14	Remote instruction required more effort from the faculty.
Question 15	I was given enough time to prepare for online lecture delivery.
Question 16	The faculty required more effort while working from home.

2.4. Factor Analysis

We carried out factor analysis using IBM SPSS Statistics (Version 27) to determine the extent to which each variable in the dataset is associated with our selected themes or factors. We performed Kaiser–Meyer–Olkin and Bartlett's Tests on the dataset of 91 faculty members. The KMO value of sampling adequacy is 0.835, as shown in Table A2 given in Appendix B, which shows the suitability of the dataset for the factor analysis. Moreover, the result of Bartlett's Test of Sphericity with an approximate chi-square value of 770.939 and a significance value of 0.000 indicates that the null hypothesis of equal variances across the variables has been rejected. This suggests that the variables in the dataset are not uncorrelated, and that factor analysis is appropriate. The communalities in the dataset are extracted using the Alpha factoring extraction method that has an initial value of 0.6 as shown in Table A3 of Appendix B. The variables with high communalities (e.g., above 0.6) are considered to be well-represented by the common factors and are retained in the analysis, while others are excluded. Table A4 provides the results of factor analysis comprising factor loadings. The scree plot in Figure A1 (Appendix B) shows that the curve is almost flattened at 4 suggesting that the eigenvalues for the additional factors are not much larger than those for the first 4 factors. This indicates that the first 4 factors account for most of the variance in the data and it is appropriate to retain them as they are likely to provide the most meaningful results as shown in Table A5.

The four main factors (F1–F4) that emerged comprise the following variables: F1 (Q1, Q2), F2 (Q4), F3(Q5–Q6, Q8–Q12), and F4(Q13, Q14, and Q16). Q3, Q5, and Q7 are omitted, and all these questions are very much related to online labs. Since fewer lab engineers (8) participated in this survey, the factor analysis outcome can be questioned, as a valid outcome requires a minimum of fifteen responses for each variable. However, this component was an important aspect of online teaching, and hence, cannot be ignored. The other outcomes confirm our grouping of questions. Although Q5–Q12, excluding Q7, can be placed in one group, as they all fall in the category of teaching from the faculty point of view, we believe that they are unique aspects of teaching, and therefore, should be discussed as separate entities.

2.5. Data Collection and Analysis

For the collection of data, the online Google form was used, and the link was shared by participants through email or WhatsApp. In this way, the responses of the participants were recorded. The analyses of the data, frequency, percentage, mean, and standard deviation, and results are discussed in the coming sections. The research was approved by the Research/Publication and Funded Project Committee at CUI with reference number CUI-LHR-ECED-22/4568. The questionnaires provided to the participants were anonymous, guaranteeing that they did not carry any information that could help in the identification of the participants. For the analysis of open-ended questions, the thematic analysis technique was used. Additionally, after re-reading the transcripts, the three main categories were thematically analyzed using an inductive approach. Similar conceptual categories were merged to create larger, overarching themes relevant to the teacher perception.

3. Results

This section presents the results of the study. Table 3 presents responses related to the platform and the preferred laboratory method used for the online mode of education. It revealed that Microsoft Teams is the most frequently used platform (70.3%), followed by Zoom (12.1%), Google Classroom (12.1%), and 5.5% used some other platforms. Live Demo is the most preferred laboratory method (35.1%), followed by Virtual Lab (20.9%), Recorded Hardware Demo (18.7%), and Simulation Demo (17.6%). In summary, faculty members and instructors believe that Microsoft Teams has been the most frequently used platform during the online mode of education, and the use of Live Demo is the preferred laboratory method.

Table 3. Platform and preferred laboratory method used.

Characteristics	Attributes					Total
Platform used	Microsoft Teams	Google Classroom	Zoom		Other	91
	70.3%	12.1%	12.1%		5.5%	100%
Preferred laboratory method	Simulation Demo	Recorded Hardware Demo	Live Demo	Virtual Lab	Other Method	91
	17.6%	18.7%	35.1%	20.9%	7.7%	100%

The results of the provision of resources for online modes of education as perceived by the participants and their breakdown are provided in Figure 1 and Table A1 in Appendix A. Only 37.76% (Mean = 2.92; SD = 1.24) of the participants are satisfied with the support provided by IT, 19.78% (Mean = 2.92; SD = 1.22) are satisfied with the digital hardware provided, and 25.75% (Mean = 2.66; SD = 1.16) are satisfied with the quality of the internet. The mean values of all three statements are less than 3.00 and an overall mean of 2.63 indicates that faculty/instructors are not satisfied with the available resources required for an online mode of education. Furthermore, in all three cases, the satisfaction rate of females (23.8%, 14.3%, and 19%) is less than that of males (41.4%, 21.4%, and 27.1%).

The results related to the delivery of contents (teaching) indicate that only 52.74% (Mean = 3.34; SD = 1.09) had prior knowledge of using the ICT devices necessary for the successful delivery of lectures. An overwhelming majority of faculty, 80.21% (Mean = 2.41; SD = 1.18), lecturers were not satisfied with the delivery of lectures when compared to F2F lectures, 83.52% (Mean = 2.30; SD = 1.03) found delivering lectures from home problematic. Similarly, 91.21% (Mean = 2.24; SD = 1.00) of the faculty were not happy with the way labs were conducted online. The mean values of all four statements are less than 3.00 (overall mean of 2.57), indicating a high level of dissatisfaction. Again, females seem less satisfied than their male counterparts in all four scenarios.

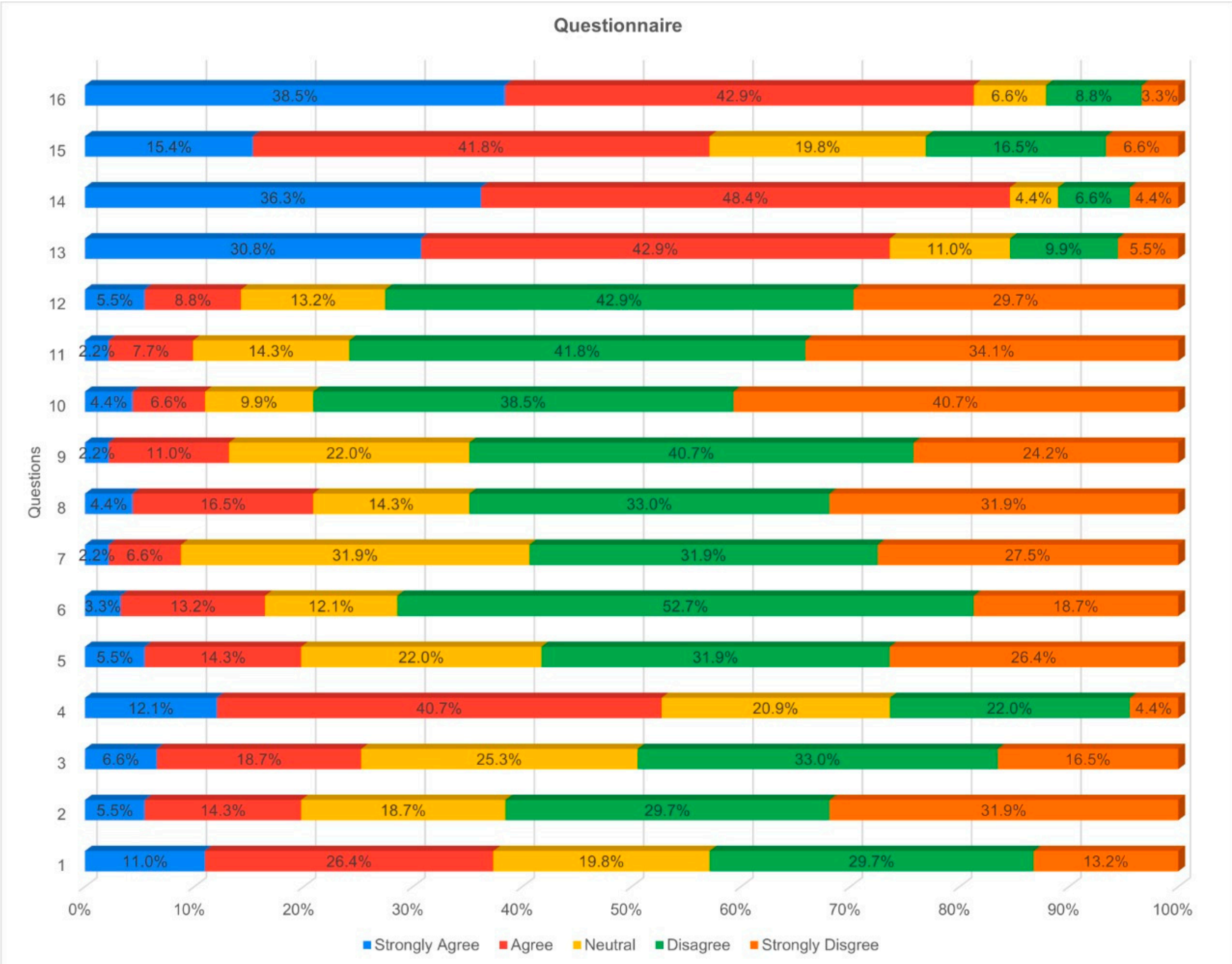

Figure 1. Graphical presentation of data for all statements.

Regarding the assessments, only 20.87% (Mean = 2.29; SD = 1.20) of the faculty was satisfied with the standard of assessment and a meager total of 13.18% (Mean = 2.26; SD = 1.02) was satisfied with the integrity maintained. The mean values of both statements were less than 3.00 (overall mean of 2.28), which reflects that they are not satisfied. Additionally, 89.01% (Mean = 1.96; SD = 1.08) of the participants are not satisfied with student–teacher interactions, 90.01% (Mean = 2.02; SD = 1.12) are not satisfied with student–student interaction, and only 14.28% (Mean = 2.18; SD = 1.00) are happy with student engagement level. An overall mean of 2.02 (SD = 1.10) indicates that the faculty is largely unsatisfied with student interaction and engagement.

Lastly, the results related to faculty workload and efforts reveal that 73.62% (Mean = 3.83; SD = 1.14) of the faculty is of the view that their workload increased, 84.16% (Mean = 4.05; SD = 1.04) think that remote instructions require more effort, 57.14% (Mean = 3.43; SD = 1.14) consider the time provided for preparation as enough, and 81.31% (Mean = 4.04; SD = 1.05) pointed out that working from home is more tedious. The mean values of all four statements are greater than 3.00 (overall mean = 3.84; SD = 1.09), indicating that faculty members believe that their workload and effort have increased, and they require more time and effort for preparing and delivering their lectures online.

Table 4 examines the perceptions of participants about the online mode of education based on their gender and position by using an independent sample *t*-test and one-way ANOVA. It reveals that there is no significant difference in the perceptions of male and female faculty members about the online mode of education and both are equally satisfied/dissatisfied. However, the results of the one-way ANOVA showed a significant difference on the basis of the positions of faculty members regarding satisfaction with the online mode of education. The Associate Professors (AP) seem to be more satisfied, and the instructors are the most annoyed with the online mode of education.

Table 4. Perceived differences based on gender and position.

S. No.	Basis	Gender/Position	*n*	Mean	df	Sig.
1	Gender	Male	70	44.97	89	0.190
		Female	21	41.86		
2	Position	Instructors	8	44.62	86	0.023
		Lecturer	40	45.53		
		Assistant Professor	25	39.44		
		Associate Professor	13	49.46		
		Professor	5	44.00		

3.1. Analysis of Open-Ended Questions

The opinion of the participants was also sought through three open-ended questions, which were analyzed using thematic analysis. The first question sought opinions on important psychomotor skills that students miss during the online mode of education. The second question was about the advantages of the online mode of education. The third question was about the disadvantages of the online mode of education. Thematic analysis was applied in three steps. First, codes were identified by reading and re-reading the responses to each question. Second, similar codes were grouped together to develop sub-themes, and then these sub-themes led to the themes. Finally, these coded, sub-themes, and themes were reexamined, and a final set of themes emerged. In this process, some of the codes and themes were either merged or deleted if needed. Thematic analysis for each of the questions was conducted separately and the results are discussed as follows.

3.1.1. Important Psychomotor Skills That Students Missed during Online Mode of Education

A frequency analysis of the text was performed after familiarization. The codes with the highest frequency derived from the content analysis of the corresponding open-ended questions include hardware, experience, students, hands-on, skills, work, experiments, teams, and communication. The words that had the same meanings were placed under the same code. These main categories were analyzed inductively resulting in the following overarching themes. Evidence-endorsing themes can be drawn from the responses to the question.

- Theme 1: no physical access to laboratories and lack of hands-on experience.

The thematic analysis revealed that there was a lack of hands-on experience as students were unable to access the labs and the same is evident in the responses of the participant.

"All skills requiring physical tasks were missed during online sessions."

"Students missed hands-on experience of hardware-oriented labs, e.g., ECA, Machines, Power related labs, etc."

- Theme 2: lack of teamwork.

It was not possible to engage in teamwork, as students were not able to meet physically and they were not used to carrying out collaborative work online.

"No teamwork, no real time understanding and, no hands-on practice."

- Theme 3: all skills requiring physical tasks were missed during online sessions.

Student missed the skills requiring physical task, such psychomotor skill and presentations, etc., which demotivates the students.

> *"A student may be good in simulations in online teaching but may lack skills in practical implementation such as soldering, PCB fabrication, electrical hardware testing, fault diagnosis due to lose grips/broken wires, machining, drilling, chamfering, casting, and molding."*

3.1.2. Advantages of Online Mode of Education

Highest frequency codes derived from the content analysis include teaching, online, available recordings, resources, flexibility, videos, saves, time, commute, activities, and availability. The codes with same meaning were merged into same category later on. These main categories were analyzed inductively resulting in the following overarching themes. Responses to the question are presented as evidence-endorsing themes.

- Theme 1: the availability of online recordings provided flexibility in routine.

The main advantage offered by the online teaching was the availability of recorded lectures, which was appreciated by the faculty as evidenced in the following response:

> *"Flexible timings. In our system there was no such advantage of online education as many students are living in remote area, so they were facing the issues."*

- Theme 2: online lectures saved travelling cost and time.

The participants' responses indicated that online lectures were not only beneficial in monetary terms but also saved the time otherwise spent on attending the lectures on campus. This is also obvious from some of the responses:

> *"No wastage of time due to daily commute, less expenses of students specially the hostilities, students may cover the syllabus even if they miss the class due to recorded lectures."*

- Theme 3: easy availability of resources.

Another benefit highlighted was the easily available teaching materials online, as this provides them with the convenience of accessing them quickly when required, as shown by the response of this participant:

> *"It is much more convenient for students and teachers as long as they have access to the material and have space to engage with online synchronous activities."*

3.1.3. Disadvantages of Online Mode of Education

Highest frequency codes derived from the content analysis of this open-ended questions include student, less, interaction, online, assessment, physical, difficult, poor, integrity, engagement, and communication. Only one code was used for words having the same meaning. These main categories were analyzed inductively resulting in the following overarching themes. Evidence-endorsing themes can be drawn from responses to the question.

- Theme 1: limited interaction and engagement.

One of the major downsides of online teaching was the lack of engagement of students during the lecture and interaction with teachers and peers inside and outside class hours. This is also clear from some of the responses given below:

> *"Most of the students were not engaged with their online sessions."*

> *"It is not possible to engage students with the practical lab work and hardware."*

> *"The interaction with students was too low, and students are not serious during online classes."*

- Theme 2: Integrity issues in assessment.

As pointed out earlier, the faculty seems really concerned about the issues related to assessment, which are discussed in more detail in the next section. The following response by one participant highlighted this issue:

"Assessment and student integrity was an issue. Also, lab performance was hard during the online mode of education."

- Theme 3: Difficult to prepare material and teach.

Faculty found it hard to prepare for lectures, as they had to redesign material to make it suitable for online delivery. They also found it hard to deliver lectures from home, as it disturbed their personal life, and the same is pointed out by some participants:

"It requires much more effort on the part of them to prepare asynchronous material and also to do synchronous activities, especially if you have young kids at home."

"It was really very hard to manage personal life during online mode of teaching."

4. Discussion

The results of this study have been discussed in five subsections for the sake of a better understanding and readability. These subsections are related to the provision of resources, delivery of content (teaching), students' assessment, students' interaction and engagement, and increased workload and effort on the part of faculty.

4.1. Provision of Resourses

The results of the quantitative analysis of the data found that most of the faculty members, especially instructors, are not satisfied with the available resources required for an online mode of education. The results of the open-ended questions revealed that key issues related to technology include lack of training for online teaching and poor internet connections. A total of 58.6% males and 76.2% females were not satisfied with the IT support. This is due to the fact that the shift to online education increased the task of IT vastly, due to which they were unable to provide the required level of services [18]. More females are unsatisfied because IT staff are predominantly males, and females are shy to contact them due to cultural values. APs are more satisfied because they might be receiving more support due to their seniority. A total of 62.5% of lab engineers (LEs) are not satisfied as they conducted labs and had to install different software, thus requiring more support, which the IT department was unable to provide not only due to shortage of staff but also due to lack of expertise. A similar pattern can be observed with hardware provided, where APs are the most satisfied and Les the least satisfied. LEs had to conduct online labs that required more hardware, whereas APs mostly teach theoretical concepts and do not need much hardware as such. Overall, the faculty is not satisfied with the hardware required as the idiosyncratic nature of engineering courses demands special hardware for teaching, which could not be updated immediately. The main reason was the financial pressure on universities and lack of provision to spend on the procurement of hardware, which was not included in the annual planning of the budget [20]. The lack of hardware resources was another issue, as students need to run multiple virtual machines for their lab work. This uses a lot of the processing power of their machines, having adverse effects on their lab work. Universities can overcome this problem by moving to cloud-based services [41]. Another challenge faced was the orientation of freshmen, which is important for success in academia. The solution to this problem is the use of technology such as virtual or augmented reality [42].

An overwhelming majority are not satisfied with the quality of the internet and again, LEs and females are least happy, and APs are the most satisfied as they spend a considerable amount of time in administration. The internet bandwidth acquired by universities is sufficient to meet requirements under normal circumstances, but when multiple students are accessing resources online at the same time, the availability of the limited bandwidth of the internet causes lagging, thus reducing the overall quality of the service. Therefore, students face difficulties accessing resources or lectures. The university should have the option to upgrade the internet bandwidth on demand or acquire other resources as and when needed [43].

4.2. Teaching (Delivery of Content)

The faculty members and instructors are not satisfied with different aspects related to the delivery of content during an online mode of education. More than 52% of the participants indicated that they have prior knowledge of the ICT devices, which is expected, as the participants are either electrical or computer engineers who are tech savvy. More males expressed proficiency with ICT devices than females, with approval rates of 55.7% and 42.9%, respectively. However, the faculty had to use new software and tools for online teaching, which they had not used before. Thus, as a novice user, they face problems with operating those devices. This is the reason behind the dissatisfaction of half of the faculty.

An overwhelming majority of faculty (80.21%) were discontented with the online delivery. There are multiple factors contributing to it, which include engagement, interaction, quality of internet access, and lack of hardware. The conduction of online labs was a real concern as none of the faculty members gave a positive response. In F2F, teaching students usually involves performing experiments in the laboratory by using engineering equipment crucial for developing psychomotor and problem-solving skills. During the COVID-19 period, the faculty was clueless about how to continue the practice of teaching in the laboratory. Students were deprived of working in labs, and they are certainly going to miss learning these skills [43]. They looked for alternative ways of compensating for the missed opportunity, such as recording experiment videos, arranging online demos, and using virtual labs [39].

In the recorded lab method, the lab instructor provided students with a video recording of the experiment being performed. The theoretical concepts of the lab were explained, followed by detailed hardware and software demonstrations. After they had watched the video, a live discussion session was also scheduled to address student queries. The students were not time-bound and could view the videos as per their convenience. This mode provided time flexibility for the students, but they could not have a live discussion session and had to wait for their designated time slot. Furthermore, at the time of recording, the instructor was not receiving any feedback from the students; they were just delivering the content without knowing whether the students were absorbing the concept or not. Additionally, this was a new phenomenon for instructors, who would spend their time figuring out the technology, wasting precious time.

In the online demo method, students used simulation tools to perform their lab tasks. Later, in the online session, lab instructors asked the students to share their screens and show the results of their assigned tasks. Students were also asked to explain and elaborate on their methodology for solving the task to avoid any forgery and plagiarism. However, some labs needed extensive hardware usage and students did not acquire important psychomotor skills. In some cases, lab instructors needed to evaluate the students for safety-related outcomes during performance, but this type of evaluation was not possible in simulations and online performance.

Both methods were demanding for the lab instructors, as they had to invest extra time preparing for online lab sessions. Many of the instructors felt uncomfortable when recording their own videos, as they were camera-shy. The female faculty were especially concerned about posting their videos online due to privacy issues and cultural values [43].

Simulation tools have become an indispensable part of engineering and many tools are available for simulating different devices or circuits under different conditions. These tools are capable of providing the learners with most of the competencies obtained in the laboratory, they were real saviors during the pandemic, and proved instrumental in continuing the teaching–learning process in engineering programs.

The virtual lab tools are downloadable software that provide access to a variety of sophisticated hardware instruments and lets the users explore various cases that are similar to the hands-on experience with hardware equipment [38]. It did not require any extra resources and a computer terminal with internet access was the only requirement to conduct the lab experiments. This concept of virtual performances of lab experiments was not very common before the COVID-19 pandemic, and it was not explored as vigorously. As a result, vendors offering such services had a monopoly and the prices offered were not affordable for many institutions.

In many courses, simulation and virtual lab tools are only enough to develop the competencies for a particular domain or subject [43]. For example, in the case of the core engineering course, Digital Logic Design (DLD), students had to design a digital circuit whose functionality is verified through simulation at the first stage. The design is then validated by implementing it on a breadboard using discrete components or on an FPGA. Simulation tools such as Modelsim and Quartus are quite convenient in this case, but they have their own limitations and could not be a substitute for hardware. The simulators can simulate logic gates for verifying functionality without considering the physical constraints of the devices. Therefore, simulation tools are very helpful in embellishing the theoretical concepts of engineering courses, but they cannot be a substitution for hands-on hardware experience. This also created frustration among the lab engineers, as they were not able to achieve learning outcomes.

In order to complement the competencies lacking due to the simulation-based labs, students on all campuses of CUI were asked to complete their hardware lab work before the start of the new semester to make up for the missing psychomotor skills. The new academic year was delayed by two weeks to create a window for both students and teachers to complete the lab work.

4.3. Student Assessment

4.3.1. Assessment Standard

Around 79% of faculty said that they were not satisfied with the standard of assessment, while 65% of them expressed total dissatisfaction over the standard of assessment during the online mode of education. Only 10% of the female and 17% of the male faculty were satisfied with the standard of assessment. This is due to new protocols of online learning, where teachers struggled with assessing the learning of the students. The traditional assessments are mostly based on the production of knowledge that cannot be applied to online teaching, as students have all the resources, and it is hard to monitor them from a distance. In addition, the lack of expertise in tools used for the development of assessments proved to be a barrier in developing a quality assessment standard.

4.3.2. Assessment Integrity

The situation was even worse when it came to integrity, where around 89% of faculty were not happy at all, the survey said. None of the females responded positively to this question. The literature revealed that performing authentic assessments was very challenging for instructors because of the lack of a reliable visualization system during assessment time [28,29]. Regarding regular on-campus student assessment, [28] stated that it is now more challenging in American high school seniors, about 70% of students admit to cheating on at least one test, and 95% of them were never caught. The most commonly used technique of online assessments by universities in Pakistan is timed computer-based assessments that require different software, a camera, and a microphone on the student's end [19,21,24]. This software disables the internet connection or any other programs on a student's computer. This is an effective way of preventing cheating, but it cannot stop the student from receiving help from an external tutor. The students taking an online assessment at home may receive help from a friend who avoids appearing on camera. Alternately, students can send questions to an external tutor and receive answers. The student may mirror the contents of the main monitor using another monitor used by another party who can easily access test questions at the same time and provide/copy answers.

The aforementioned issues can be avoided by conducting the assessments on campus. The students enrolled in a course can take an assessment at the same time or independently, in accordance with their convenience. Students may come to campus to take the assessment, go to the designated place by themselves, take their assessment online via the assigned computer, and then they may leave without interacting with other students. The faculty need to develop a sufficient pool of questions minimizing the chance of repetition of questions. The culture of cheating can also be discouraged by educating students about ethics at an early stage. Imposing severe penalties for cheating and plagiarism might also refrain students from cheating. In addition, the use of oral assessments, interviews, and essay questions might be very convenient in evaluating the students' achievements accurately, leaving minimal or no room for cheating [44]. These methods allow for assessing the comprehension of the students and their high-level thinking, leaving very little room for the use of unfair means. Other measures include randomizing the questions or distracters, putting one question per page, not allowing backtracking, locking down the computer or browser, and using randomized log-in.

4.4. Student Interaction and Engagement

The results of the quantitative analysis of the data found that faculty members and instructors are not satisfied with the level of interaction and engagement during the online mode of education. The importance of both students' interaction and engagement in the students' learning is evident in the literature.

4.4.1. Student–Teacher Interaction

The majority of the faculty, around 89 percent, were not satisfied with student–teacher interaction. The APs and LEs were relatively more satisfied, with 31% and 25% positive responses, respectively. The LEs conduct labs that require more interaction and APs are able to interact with students more due to their experience. Student–teacher interaction is one of the most important aspects of the student learning process, and otherwise, educational institutions can only be based on textbooks, recorded videos, and evaluation systems [5,38,39]. The percentage of this interaction may differ from one student to another and affects students' learning. The reasons identified by teachers include low attention span, absence of monitoring, limited time for interaction, interruption in the supply of electricity, weak internet connection, lack of immediate feedback, and technical ignorance. Most of the interaction with students took place through email, which was not real-time and also consumed a lot of time. Cultural values and privacy were also reasons behind the low interaction as many students, especially females, refused to appear on camera due to these reasons. The teacher lost the opportunity for implicit interaction with students, which takes place by observing facial expressions or eye contact [45].

4.4.2. Student–Student Interaction

The faculty overall was not satisfied with the level of student–student interaction inside and outside class, which can largely be attributed to the absence of methods to do so. In addition, students do not feel pressure to do so if they do not see each other physically. The interaction could be enhanced by using breakout rooms and discussion boards. This peer interaction is important for training and knowledge sharing. This is one of the most important aspects of university teaching, and students are offered space and time for interaction. In addition, universities are recognized due to their model, which involves the interaction between students and universities at various levels. A deviation from the basic model means students are not benefitting fully from the resources that urge them to pursue their degree. It has a huge impact on student competencies and helps them to develop self-organization and self-discipline.

4.4.3. Student Engagement and Attention

A high percentage of teachers, around 86%, were not happy with the level of engagement. They found it challenging to gain students' attention and keep them engaged during lecture time. This can be attributed to the low attention span of students, passive teaching, distractions at home, the use of digital devices for social media, and the low-quality internet. When attending F2F lectures, students present in the class are often driven by the environment to pay attention to the teaching–learning activities. The presence of the lecturer in the class also plays its role and students pay attention to the teacher, as they have been trained for it over the years. In the case of online teaching, students can simply log in and move away without paying any attention to the teaching activities. Turning on the camera may help but it is not feasible due to cultural and privacy issues, as discussed earlier. Another reason is the lack of connectivity with students. The lecturer is connected to the students through technology and students never feel that they are being addressed. They are not compelled to pay attention or motivated to take part in the activities. In other words, the lecturer is teaching computers and computers respond to the lecturer, a mechanical response lacking passion and feeling.

Some of the strategies that may potentially be used to engage students include polls, online quizzes, students playing the role of the teacher, discussion, and screen-sharing, in-class activities, game-based assessments, use of leaderboards, breakout rooms, simulations, demonstrations, and interactive whiteboards [21,22,42]. Carrying out collaborative activities can foster engagement, but again, the lack of a sense of connectivity during the activities does not help [45]. Increasing the total number of assessments per semester may also help in engaging students in online classes.

4.5. Increased Workload and Effort on the Part of Faculty

4.5.1. Faculty Overloaded

The academic community responded well to the pandemic by adopting remote teaching, but it also increased their workload and disturbed their work–life balance. The results of the quantitative analysis of the data revealed that around 75% of the faculty members believe that workload and effort had increased, and a higher percentage of females and Assistant Professors said so, 86% and 84%, respectively. They are of the opinion that they had to invest more time on preparing and delivering their lectures [46–48]. The main factors contributing to faculty load are discussed below.

4.5.2. Familiarity with Technology

Teaching online requires instructors to be sufficiently trained and to be familiar with the technology. Unfortunately, they were not well prepared to meet the challenges presented by online teaching, resulting in extra stress when coping with these challenges. Creating online content for the students was not easy, especially when all the supporting staff was also stuck at home. They had to learn the use of new technologies for the successful delivery of the content in parallel with the development of the material. They had to develop proficiency and become powerful users of global teaching platforms. In short, they needed to master digital media and new software in order to ensure the proper delivery of the lectures [47]. Learning new tools is very time-consuming and presents an extra burden that is not even noticed.

4.5.3. Redesigning of the Courses

Traditionally, the courses have been designed for F2F delivery and were never meant to be offered over the internet. This means that the material should be adapted for online and web-based delivery [49,50]. Two major components of the course that needed to be redesigned were the planning of in-class activities to engage students and assessments. Similarly, assessments designed for evaluating the achievement of students' learning outcomes in a traditional examination setting were not valid for online teaching.

4.5.4. Redesigning Teaching and Learning Activities

In F2F teaching, students are engaged through interaction that is not possible when teaching online. Faculty were forced to design online activities for engaging and motivating their students [51]. Online tools such as Kahoot, Mentimeter, XorroQ, and Socarno, are helpful for developing activities for engaging students and providing an entertaining environment. Even the TikTok application has been used recently in many class activities [52]. Developing such activities from scratch required a considerable amount of time.

4.5.5. Redesigning Assessments

Paper-based assessments are not applicable for online teaching and ensuring academic integrity is another issue that needs attention. This requires redesigning assessments in a way that minimizes plagiarism and ensures the achievability of learning outcomes by students working from home. The integration of preventive measures into assessment to counter threats to validity for stopping cheating requires considerable effort from the faculty. However, the use of course management systems (CMS) can be helpful in developing such assessments, which allows them to develop different types of questions, such as problem-solving with the upload option, text-typing questions, multiple choice, and true or false questions [53,54]. However, universities in Pakistan generally lack specialists experienced in administrating online courses, as this has not been the mode of delivery in the past. This effort is worth it as it has value in the sense that the bank of questions can be used in different events, can be auto-graded, and provides immediate feedback [44,53].

4.5.6. Feedback to Students

Feedback is an important component of the teaching–learning process. In online teaching, most of the feedback is asynchronous and through correspondence, which is not only time consuming but inefficient as well. Teachers struggled to provide meaningful feedback in a timely manner, essential for student motivation and confidence. An increase in the number of assessments and a decline in student–teacher interaction also contributed to the efforts and workload of an already saturated faculty. Additionally, due to lack of experience using CMS, teachers could not exploit the features to the full extent, which could help them in expediting the process of providing feedback with less effort. Providing feedback to students for every assessment and activity is very important in tracking students' behavior and response [55,56].

4.5.7. Assessing Student Lab Work during the Lab

Assessing lab work is the trickiest part of the online mode of education. To elaborate, an example of the electrical and computer engineering department is being discussed. In said department, almost every second subject had its laboratory work, and only a few labs can be conducted online and covered through simulation tools. However, many other labs need extensive hardware usage. For example, if we consider power-related courses, they are being taught with the help of practical hands-on experiments on hardware. The hardware resources for such labs are quite expensive and it is impossible for the students to have their own equipment. Many simulation tools are available for said domains, but with limitations. Moreover, simulation tools cannot be a substitute for practical hands-on experience, especially in the outcome-based education (OBE) system. The students need to learn about the safety of equipment and users while using the equipment [57]. During practical work, they need to troubleshoot, and they grasp concepts that cannot be delivered during theoretical lectures. Similarly, psychomotor is another very important skill that needs to be developed among students in the OBE system, which is possible by hands-on experience of the equipment. The development of such skills is compromised in the absence of hardware resources.

To highlight the online lab conduction issues in detail, we are taking an example of a lab-oriented course, i.e., Digital Logic Design (DLD). Considering the course curriculum, the course learning outcomes (CLOs) and program learning outcomes (PLOs) are specified in Table 5. There are four lab CLOs mapped on respective PLOs, and these four lab CLOs, along with theoretical CLOs, need to be achieved by a student to complete the course. Here, only lab CLOs are being considered and discussed.

Table 5. Course learning outcomes of digital logic design.

CLO	CLO Statement	PLO Statement
1	To analyze and design combinational and sequential logic circuits using software and hardware platforms.	**Design/Development of Solutions:** an ability to design solutions for complex engineering problems and design systems, components or processes that meet specified needs with appropriate consideration for public health and safety, cultural, societal, and environmental considerations. (cognitive domain)
2	Follow the software and hardware tools to reproduce the response of the digital logic circuits using software and hardware platforms.	**Modern Tool Usage:** an ability to create, select and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and modeling, to complex engineering activities, with an understanding of the limitations. (psychomotor domain)
3	To explain and write effective lab reports of experiments performed during lab.	**Communication:** an ability to communicate effectively, orally, as well as in writing, complex engineering activities with the engineering community and with society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions. (affective domain)
4	To demonstrate the working of a digital logic circuit designed individually and through teamwork using software and hardware platforms.	**Individual and Teamwork:** An ability to work effectively, as an individual or in a team, on multifaceted and/or multidisciplinary settings. (affective domain)

In this course, students need to design a solution for a real-word problem using digital logic gates. For that, firstly, students need to design the solution on paper using truth tables, Boolean algebra, K-Maps and logic gate designing techniques. Secondly, the students are supposed to simulate their designed solution on some simulation tool to check and verify their desired outcomes/outputs. Thirdly, students need to implement their design on hardware using basic logic gate ICs and validate desired outputs. The first and third CLOs can be achieved by going through theoretical concepts and writing an effective report, respectively. The second CLO will be implemented through online teaching, but there is a fourth that is related to teamwork. The student can perform tasks individually at home by buying inexpensive components, but they also need to learn to work in a team while working on hardware, so that part of CLOs will remain partially uncovered. To resolve this issue, students were called to perform on campus as discussed in the earlier section.

From the above case study, it can be concluded that there are a few courses and laboratories that can be completed online but by compromising the quality and learning outcome of that course. On the other hand, instructors need to explore new ways of online teaching for some of the labs that cannot be completed online in true letter and spirit. One of the potential solutions could be augmented reality. Augmented reality is already famous among young people, and it can provide a better substitution for hardware equipment [42,58].

4.5.8. Remote Instructions Required More Work

Most of the faculty, around 85%, were of the view that remote instructions required more effort from the faculty. A higher percentage of females (90.5%) and Assistant Professors (92%) were of the opinion that they had to put in more effort. Managing online classes is challenging due to the lack of interaction, and it takes an emotional toll on the faculty. Most of communication is written, which requires more effort from the teacher [59]. The absence of teaching means that they had to make effort throughout the semester and deal the challenges on the go.

4.5.9. Time for Preparation

Only 57% of the faculty agreed that they were given enough time to prepare for the online lecture. Although the closure of universities did provide the faculty time to prepare for online teaching, this time was not enough. As pointed out by [49], six to nine months are required to prepare a course before it is ready for delivery. However, due to an emergency, the faculty could not afford the systematic course design and had to perform this task in a very short span of time. The absence of supporting staff for online teaching exacerbated the situation and proved stressful for instructors. The courses were designed without following the complete process of online course design [50].

4.5.10. More Efforts when Working from Home

Around 81% of the faculty think that working from home required more efforts despite the fact that they did not need to commute for lectures. This is because families were confined to their homes; the delivery of lectures from home interfered with their domestic life as they had to look after their families and supervise children as well. A very high percentage of female members of faculty, around 90%, responded positively to this point, which is quite understandable in the context of a culture where females are expected to handle household chores and take care of children. Similarly, more than 87% of lab engineers were of the same opinion because setting up lab equipment at home requires effort. They had to put in extra emotional labor in order to coach their students and grab their attention [48].

4.6. Recommendations for the Future

If this type of catastrophe hits in the future, the education sector should be able to respond swiftly. Therefore, as per this study, here are some of the recommendations to minimize the academic loss of students in the future.

- We recommend that ad hoc measures taken during the emergency should be transformed into lasting reforms;
- Keeping in view the advantages offered by online learning, such as flexibility and cost-effectiveness, it is recommended that universities in Pakistan should offer a hybrid mode of learning, where F2F lectures are also broadcasted online in real-time as well. Students should be given the choice to attend either lecture mode;
- Recorded lecturers were good support to the students. Therefore, the culture of recording lectures and making them available through LMS will also be quite helpful for students;

- Blended learning should be incorporated by universities for future teaching. It has stronger learning outcomes as it combines the best of both worlds. Making resources available online will allow us to benefit from the investment made in building IT infrastructure and capacity during a pandemic. This will also ensure that academic activities continue even if some disruption happens in the future. In other words, there is no need to close universities because of inclement weather or political unrest;
- The availability of online lectures is especially beneficial for students at risk of dropping out or from marginalized backgrounds;
- Televisions and cable infrastructure are more common and reliable in Pakistan. It is recommended to air the instructional content using this medium instead of using smartphones, which are expensive and suffer from connectivity issues;
- Institutions have already unearthed the importance of investing in good quality Internet, video conferencing, and faculty development. Additionally, university faculties have discovered many tools to engage students online and learned from their experience when and how digital instructions work best. These practices and the use of tools should be continued in the F2F classroom for evidence-based teaching to engage students. The faculties should integrate technology into instruction and learning, and universities should create opportunities for professional development so that this integration is achieved in an effective way.
- Universities should also make efforts to provide free and open-source technologies for students and teachers. All stakeholders should ensure that educational resources are used for advancing the interests and abilities of learners and to advance private aims.
- We recommend continuing the use of computer-based or computer-assisted assessments. This method is environmentally friendly, saves resources, and reduces the chance of misconduct. Other advantages include the availability of immediate results and feedback. This method can be used for synchronous/asynchronous and on-campus/off-campus settings. If the test is asynchronous and off campus, it is advised to include more open-ended and formative questions to reduce the chances of cheating [60].
- Developing a database of questions for exams, randomly selecting questions, and changing the order of the questions may help limit cheating. Lastly, computer-based assessment generates a wealth of data that can further be analyzed to make predictions and identify gaps.
- Academia should continue to use methods and mechanisms developed for assessing students during the COVID-19 crisis and use this as an opportunity to transform existing assessment mechanisms. Furthermore, the open-book exam (OBE) or open-resource exam [53], which allows students to consult resources during the exam, should be promoted. This eliminates the need for proctoring and promotes higher-order thinking as well. Furthermore, assessments focusing on the application of concepts instead of reproducing the knowledge are most likely to minimize the chances of misconduct [54].
- For the lab work, the use of virtual prototyping and other remote lab tools has been quite successful [61,62]. Therefore, it is recommended that the use of such tools should not discontinue, as it will allow the students to engage in lab work outside laboratory hours, providing them with more control and flexibility.
- Furthermore, academia is encouraged to work insistently in this domain and develop customized lab-oriented applications to perform practical work remotely at their own will. This will also help in minimizing the control of private companies on educational platforms [61].

In short, universities in Pakistan need to develop a culture of online teaching and learning, as it may be required again in the future. Recently, the provincial government in Pakistan restricted school activities to four days a week in Lahore to improve the air quality due to smog. In order to avoid study losses, the schools conducted online classes for the fifth day. A similar practice was carried out when the city was closed due to political unrest.

5. Conclusions

This paper highlights the online teaching and learning practices of an engineering program offered at Pakistani universities during the COVID-19 pandemic. The study reveals that on average, teachers have a positive perception of virtual teaching amid COVID-19 of reducing the learning gap and shaping pupils' future during a crisis. However, they also encountered several obstacles in online teaching, such as technical issues, student engagement issues, difficulties in online exams and assessments, etc. The lesson was learned in view of enhancing and improving the online delivery of engineering students. In particular, it is recommended that universities redesign their courses by integrating technology in the delivery of content and in the assessment of learning outcomes. The provision of resources and essential training for the faculty, staff, and students may be beneficial in this regard.

The limitation of this study involves the procurement of data from fewer faculty members of different universities with multiple campuses. Furthermore, this study was mainly quantitative in nature, with a set of open-ended questions. Conducting a qualitative survey with in-depth interviews could yield additional conclusions. Despite the limitations, the findings provide insight into the factors that contribute to the success and downsides of online teaching modalities in Pakistan during COVID-19 in several academic fields. Finally, there is no doubt that this journey was quite stressful for the faculty teaching in universities in Pakistan, but they worked hard to avoid disruptions in the teaching and learning processes. In the process, they have learned valuable lessons and gained good experience, which has prepared them for a smooth shift to the online mode without much effort during any emergency.

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Data Availability Statement: The datasets used and/or analyzed in the current study are available from the corresponding author upon reasonable request.

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

Appendix A

Table A1. Breakdown of responses.

Questions	Answers	Male	Female	Professor	Associate Professor	Assistant Professor	Lecturer	Lab Engineer/ Instructor
I was satisfied with IT support provided for online mode of education	A+SA DA+SDA N	29 (41.4%) 27 (38.6%) 14 (20%)	5 (23.8%) 12 (57.1%) 4 (19%)	1 (20%) 1 (20%) 3 (60%)	8 (61.5%) 3 (23.1%) 2 (15.4%)	6 (24%) 14 (56%) 5 (20%)	16 (40%) 17 (42.5%) 7 (17.5%)	3 (37.5%) 4 (50%) 1 (12.5%)
I was satisfied with the digital hardware provided for online mode of education	A+SA DA+SDA N	15 (21.4%) 41 (58.6%) 14 (20%)	3 (14.3%) 15 (71.4%) 3 (14.3%)	2 (40%) 2 (40%) 1 (20%)	5 (38.5%) 6 (46.2%) 2 (15.4%)	0 (0%) 20 (80%) 5 (20%)	9 (22.5%) 25 (62.5%) 6 (15%)	2 (25%) 3 (37.5%) 3 (37.5%)
I was satisfied with the quality of internet facilities during online mode of education	A+SA DA+SDA N	19 (27.1%) 30 (42.9%) 21 (30%)	4 (19%) 15 (71.4%) 2 (9.5%)	0 (0%) 2 (40%) 3 (60%)	7 (53.8%) 4 (30.8%) 2 (15.4%)	4 (16%) 17 (68%) 4 (16%)	9 (22.5%) 21 (52.5%) 10 (25%)	3 (37.5%) 1 (12.5%) 4 (50%)
I had prior knowledge of using ICT devices for online mode of education	A+SA DA+SDA N	39 (55.7%) 16 (22.9%) 15 (21.4%)	9 (42.9%) 8 (38.1%) 4 (19%)	2 (40%) 1 (20%) 2 (40%)	8 (61.5%) 3 (23.1%) 2 (15.4%)	11 (44%) 9 (36%) 5 (20%)	24 (60%) 8 (20%) 8 (20%)	3 (37.5%) 3 (37.5%) 2 (25%)
I was satisfied with the online delivery of lecture as compared to face-to-face delivery	A+SA DA+SDA N	14 (20%) 42 (60%) 14 (20%)	4 (19%) 11 (52.4%) 6 (28.6%)	3 (60%) 1 (20%) 1 (20%)	3 (23.1%) 7 (53.8%) 3 (23.1%)	1 (4%) 21 (84%) 3 (12%)	9 (22.5%) 19 (47.5%) 12 (30%)	2 (25%) 5 (62.5%) 1 (12.5%)
I did not face any problem while delivering lecture from home	A+SA DA+SDA N	13 (18.6%) 48 (68.6%) 9 (12.9%)	2 (9.5%) 17 (81%) 2 (9.5%)	2 (40%) 3 (60%) 0 (0%)	3 (23.1%) 8 (61.5%) 2 (15.4%)	1 (4%) 22 (88%) 2 (8%)	8 (20%) 26 (65%) 6 (15%)	1 (12.5%) 6 (75%) 1 (12.5%)
I was satisfied with the conduction of lab experiments during online mode of education	A+SA DA+SDA N	8 (11.4%) 38 (54.3%) 24 (34.3%)	0 (0%) 16 (76.2%) 5 (23.8%)	0 (0%) 2 (40%) 3 (60%)	2 (15.4%) 7 (53.8%) 4 (30.8%)	1 (4%) 14 (56%) 10 (40%)	5 (12.5%) 26 (65%) 9 (22.5%)	0 (0%) 5 (62.5%) 3 (37.5%)
I was satisfied with the standard of assessments during online mode of education	A+SA DA+SDA N	17 (24.3%) 44 (62.9%) 9 (12.9%)	2 (9.5%) 15 (71.4%) 4 (19%)	0 (0%) 2 (40%) 3 (60%)	4 (30.8%) 8 (61.5%) 1 (7.7%)	3 (12%) 21 (84%) 1 (4%)	10 (25%) 23 (57.5%) 7 (17.5%)	2 (25%) 5 (62.5%) 1 (12.5%)
I was satisfied with the maintained integrity of assessments during online mode of education	A+SA DA+SDA N	12 (17.1%) 44 (62.9%) 14 (20%)	0 (0%) 15 (71.4%) 6 (28.6%)	0 (0%) 3 (60%) 2 (40%)	4 (30.8%) 6 (46.2%) 3 (23.1%)	1 (4%) 22 (88%) 2 (8%)	5 (12.5%) 23 (57.5%) 12 (30%)	2 (25%) 5 (62.5%) 1 (12.5%)
I was satisfied with the student teacher interaction during online mode of education	A+SA DA+SDA N	9 (12.9%) 53 (75.7%) 8 (11.4%)	1 (4.8%) 19 (90.5%) 1 (4.8%)	0 (0%) 4 (80%) 1 (20%)	4 (30.8%) 8 (61.5%) 1 (7.7%)	1 (4%) 23 (92%) 1 (4%)	3 (7.5%) 32 (80%) 5 (12.5%)	2 (25%) 5 (62.5%) 1 (12.5%)
I was satisfied with the student-student interaction during online mode of education	A+SA DA+SDA N	9 (12.9%) 52 (74.3%) 9 (12.9%)	0 (0%) 17 (81%) 4 (19%)	0 (0%) 5 (100%) 0 (0%)	4 (30.8%) 9 (69.2%) 0 (0%)	1 (4%) 21 (84%) 3 (12%)	2 (5%) 28 (70%) 10 (25%)	2 (25%) 6 (75%) 0 (0%)
I was satisfied with the engagement of students during online mode of education	A+SA DA+SDA N	12 (17.1%) 48 (68.6%) 10 (14.3%)	1 (4.8%) 18 (85.7%) 2 (9.5%)	1 (20%) 4 (80%) 0 (0%)	4 (30.8%) 9 (69.2%) 0 (0%)	2 (8%) 19 (76%) 4 (16%)	5 (12.5%) 28 (70%) 7 (17.5%)	1 (12.5%) 6 (75%) 1 (12.5%)
The faculty workload increased during the Covid19	A+SA DA+SDA N	49 (70%) 13 (18.6%) 8 (11.4%)	18 (85.7%) 1 (4.8%) 2 (9.5%)	3 (60%) 1 (20%) 1 (20%)	9 (69.2%) 4 (30.8%) 0 (0%)	21 (84%) 3 (12%) 1 (4%)	29 (72.5%) 4 (10%) 7 (17.5%)	5 (62.5%) 2 (25%) 1 (12.5%)
Remote instruction required more efforts from the faculty	A+SA DA+SDA N	58 (82.9%) 9 (12.9%) 3 (4.3%)	19 (90.5%) 1 (4.8%) 1 (4.8%)	4 (80%) 1 (20%) 0 (0%)	11 (84.6%) 2 (15.4%) 0 (0%)	23 (92%) 2 (8%) 0 (0%)	34 (85%) 3 (7.5%) 3 (7.5%)	5 (62.5%) 2 (25%) 1 (12.5%)
I was given enough time to prepare for online lecture delivery	A+SA DA+SDA N	40 (57.1%) 16 (22.9%) 14 (20%)	12 (57.1%) 5 (23.8%) 4 (19%)	1 (20%) 2 (40%) 2 (40%)	8 (61.5%) 2 (15.4%) 3 (23.1%)	12 (48%) 7 (28%) 6 (24%)	26 (65%) 9 (22.5%) 5 (12.5%)	5 (62.5%) 1 (12.5%) 2 (25%)
The faculty required more efforts while working from home	A+SA DA+SDA N	55 (78.6%) 11 (15.7%) 4 (5.7%)	19 (90.5%) 0 (0%) 2 (9.5%)	3 (60%) 2 (40%) 0 (0%)	10 (76.9%) 3 (23.1%) 0 (0%)	21 (84%) 3 (12%) 1 (4%)	33 (82.5%) 2 (5%) 5 (12.5%)	7 (87.5%) 1 (12.5%) 0 (0%)

Appendix B

Table A2. KMO and Bartlett's Test.

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.835
Bartlett's Test of Sphericity	Approx. Chi-Square	770.939
	df	120.000
	Sig.	0.000

Table A3. Communalities.

	Initial
I was satisfied with IT support provided for online mode of education	0.601
I was satisfied with the digital hardware provided for online mode of education	0.589
I was satisfied with the quality of internet facilities during online mode of education	0.382
I had prior knowledge of using ICT devices for online mode of education	0.332
I was satisfied with the online delivery of lecture as compared to face to face delivery	0.658
I did not face any problem while delivering lecture from home	0.450
I was satisfied with the conduction of lab experiments during online mode of education	0.413
I was satisfied with the standard of assessments during online mode of education	0.645
I was satisfied with the maintained integrity of assessments during online mode of education	0.702
I was satisfied with the student teacher interaction during online mode of education	0.716
I was satisfied with the student student interaction during online mode of education	0.667
I was satisfied with the engagement of students during online mode of education	0.682
The faculty workload increased during the Covid19	0.717
Remote instruction required more efforts from the faculty	0.744
I was given enough time to prepare for online lecture delivery	0.216
The faculty required more efforts while working from home	0.564

Extraction Method: Alpha Factoring.

Table A4. Total Variance Explained.

Factor	Initial Eigenvalues			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative%	Total	% of Variance	Cumulative%
1	6.008	37.552	37.552	4.164	26.028	26.028
2	2.462	15.387	52.939	2.278	14.237	40.265
3	1.581	9.884	62.823	1.788	11.177	51.442
4	1.057	6.607	69.431	1.313	8.204	59.646
5	0.754	4.713	74.143			
6	0.688	4.303	78.446			
7	0.666	4.161	82.607			
8	0.526	3.291	85.897			
9	0.429	2.683	88.581			
10	0.386	2.411	90.992			
11	0.354	2.213	93.205			
12	0.322	2.015	95.220			
13	0.250	1.559	96.780			
14	0.216	1.349	98.129			
15	0.166	1.039	99.168			
16	0.133	0.832	100.000			

Extraction Method: Alpha Factoring.

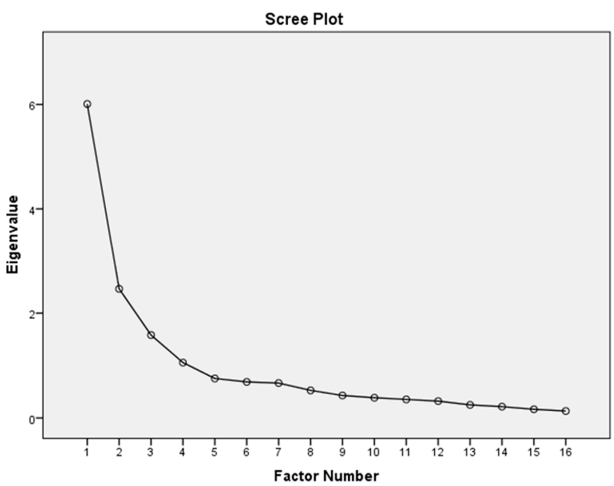

Figure A1. Scree Plot.

Table A5. Rotated Factor Matrix [a].

	Factor			
	1	2	3	4
I was satisfied with the standard of assessments during online mode of education	0.805			
I was satisfied with the maintained integrity of assessments during online mode of education	0.750			
I was satisfied with the student student interaction during online mode of education	0.737			
I was satisfied with the student teacher interaction during online mode of education	0.732			0.336
I was satisfied with the engagement of students during online mode of education	0.727			0.377
I was satisfied with the online delivery of lecture as compared to face to face delivery	0.713			
I did not face any problem while delivering lecture from home	0.608		0.343	
I was satisfied with the quality of internet facilities during online mode of education	0.387		0.301	0.302
Remote instruction required more efforts from the faculty		0.881		
The faculty workload increased during the COVID-19		0.854		
The faculty required more efforts while working from home		0.761		
I was satisfied with IT support provided for online mode of education			0.829	
I was satisfied with the digital hardware provided for online mode of education			0.798	
I had prior knowledge of using ICT devices for online mode of education				0.577
I was satisfied with the conduction of lab experiments during online mode of education	0.392			0.478
I was given enough time to prepare for online lecture delivery				0.376

Extraction Method: Alpha Factoring; Rotation Method: Varimax with Kaiser Normalization [a]; [a]: Rotation converged in 6 iterations.

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