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Factor Model for Online Education during the COVID-19 Pandemic Using the IoT

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Abstract: Coronavirus disease (COVID-19) has spread quickly around the globe. COVID-19 has affected the education sector due to partial or complete lockdowns that were implemented throughout the world between 2019 and 2022. This pandemic severely affected the education sectors in developing countries such as Pakistan. All the educational institutions in Pakistan turned to online education. However, the education sector lacked the teaching experts, digital experts, the Internet of Things (IoT), and resources needed for online education. The shift from traditional to online education has created many challenges for developing countries during a pandemic such as COVID-19, for example, access to the IoT. This paper aims to introduce the factor model (F model), which will provide guidelines for the government and universities for minimizing the deficiencies related to online education. The F-model will identify all the factors that affect the performance and guide the user about their importance. This will allow the user to resolve that issue and improve the performance of their department or institution. Thus, the F model will benefit the education sector by mitigating the challenges related to online education. The F model is not only confined to online education but can be operated in the fields of science and industry for data extraction and the calculation of results. First, the data is collected physically and online through a student survey related to the challenges of online education during a pandemic. The data extraction and the calculation of the results are carried out using the F model. The results of the survey are alarming and the government has a lot of work to do to improve online education using the IoT. According to the F model, the government should take serious action to improve the performance of students, teachers, and all education sectors not only during the COVID-19 pandemic but also for possible future pandemics.

Keywords: COVID-19; online education; developing countries; F model; challenges; factors; IoT

Citation: Khan, F.; Tarimer, I.; Taekeun, W. Factor Model for Online Education during the COVID-19 Pandemic Using the IoT. *Processes* **2022**, *10*, 1419. https://doi.org/10.3390/pr10071419

Academic Editors: Faisal Jamil and Shabir Ahmad

Received: 4 June 2022
Accepted: 18 July 2022
Published: 21 July 2022

1. Introduction

1.1. Overview

COVID-19 has spread globally since November 2019 and has affected almost the entire world. It disrupted socio-economic chains worldwide, with more than 3 billion people affected by partial or complete lockdowns. By 18 September 2021, 228,546,002 coronavirus cases had been reported worldwide, as well as 4,695,368 deaths due to the virus [1]. Education has been seriously affected and millions of students were not able to complete their courses due to the online nature of their classes. During COVID-19, almost all educational institutions converted to online education. The widespread technological revolution, including the easy accessibility and non-stop connectivity of smartphones, tablets, mobiles, DSL, 4G, and 5G, etc., provided the opportunity for online education. Many advanced countries began online education with well-established laboratories and highly qualified and trained faculty members. However, this was not the case with most universities, colleges, and schools in Pakistan. The challenges of executing online education

in a developing country such as Pakistan are greater than those in technologically advanced countries such as South Korea, Russia, America, China, and Japan [2–4].

The Internet of Things (IoT) refers to the billions of physical objects connected to the internet for data collection and exchange with other digital devices. The IoT is a huge system of interrelated digital devices that save and transfer information to neighboring devices, and hence it is considered the ecosystem of digital devices. The IoT is useful for digital devices as they can remotely access the existing infrastructure. The education system is taking advantage of the IoT in many applications to ensure class productivity and attendance. Similarly, it can reform traditional teaching methods, paper textbooks, curricula, learning processes, and connectivity between teachers and students. Some benefits of the application of the IoT in education include management efficiency, improved resource management, real-time data collection, and global interconnectivity [5].

The IoT allows digital devices to collect data on the surrounding environments to improve social, procedural, and industrial processes but comes with some security challenges [6–8]. To overcome security attacks in the IoT, challenges such as data volume, privacy protection, resource limitations, scalability, heterogeneity, interoperability, autonomous control, attack resistance, etc., must be resolved [9]. These security attacks include end-device attacks, communication-channel attacks, sensory data attacks, DoS attacks, and software attacks.

A recent survey by the United Nations Educational, Scientific, and Cultural Organization (UNESCO) showed that closures of educational institutions affected the results for many students, especially school-aged children, and that online classes are not producing the same promising results as in the physical classroom, which could affect students' futures. Teachers and students in Pakistan were forced to use online learning, a previously unknown and untested method in Pakistan, through various applications such as Hangouts, Facebook Live, Google Classroom, Zoom, Edmodo, WhatsApp, etc., but failed to achieve the desired results [10–12].

The Higher Education Commission of Pakistan (HEC) did its best to begin online classes but faced many challenges because only 36.86% of the population in Pakistan had access to broadband internet according to a report published by the Pakistan Telecommunication Authority (PTA) [13–15]. It should also be noted that only 10% of those with internet access had the type of high-speed connection needed for online education. The other 26% had significantly lower-speed connections that can be used for Facebook, WhatsApp, etc., but not for online education. The HEC provided technical assistance to colleges and universities with many online education policies. However, due to a lack of resources, the policies of HEC did not offer promising results [16,17]. Furthermore, weak financial support, a shortage of trained faculty members, and limited access to internet facilities/technology affected students' abilities in an online environment [18,19]. During the COVID-19 pandemic, societies have been attentive to the indications of the disease. Therefore, a target group of knowledgeable and organized people in the education sector should be nominated to inform sick people about the relevant authorities. This decreases the hazards of spreading the virus in the education sector. Likewise, some IoT-based applications should be offered in the education sector that are linked to the healthcare system in order to receive a rapid response. This article shows all the transmission technologies such as wired networks, wireless networks [20], mobile ad hoc networks [21,22], and sensor networks [23–25], which are necessary for the IoT. In [26], the architecture of the IoT is explained along with the multiple challenges that are relevant to the progress and distribution of IoT applications.

1.2. Contribution and Scope

This paper aims to highlight the challenges faced by students and teaching faculties in Pakistan due to the unprecedented COVID-19 situation and offers a model to present some possible solutions for the future based on available resources in Pakistan. The scope of this paper is not limited to Pakistan and COVID-19 but can improve the quality of online education in all parts of the world and help prepare for other unprecedented situations in

the future. Furthermore, this paper will enable the government and the education sector to build a well-developed online education system to facilitate students and prepare them for future lockdowns. The contributions are as follows:

- Introduction of the novel F model.
- Collection of data on online education through a survey.
- Guidelines for the government and educational institutions related to online education during COVID-19 and future pandemics.
- Challenges of online education during COVID-19 and future pandemics.
- Future directions for online education during COVID-19 and future pandemics using the F model

1.3. Organization of the Paper

The paper is organized in the following way. Section 2 describes the challenges and limitations of online education during COVID-19. Sections 3–6 explain the methodology of the factor model along with details of population and sample sizes, materials, and procedures. Section 7 explains the F model along with a possible equation and examples. Section 8 explains the results and survey form for the students and faculty. Section 9 describes the results and the future directions for educational institutions and governments in developing countries. Finally, Section 10 discusses the conclusion.

2. Literature Review

The studies in [27,28] showed different problems related to online education, including plagiarism issues, the late submission of tasks, a lack of internet or weak internet, a lack of digital devices, etc. Furthermore, the challenges of online education in Pakistan were shown to be different from those Europe and America. The work in [29] studied the challenges related to online learning in Pakistani universities and found a lack of access to computers and other digital devices, technical issues, unawareness of computers and their applications, privacy issues, and English language problems. The study in [30] showed that the challenges faced by students with regard to online education were related to networking problems, technical problems, financial problems, lack of access, and lack of support from the institution and faculty members. All papers emphasized that online education is essential and that the government should take serious action to improve online education in Pakistan.

Nowadays, research is ongoing on the impact of COVID-19. Many studies are conducted using questionnaires from students and cover topics such as the acceptance level of online education [31], challenges of online education in Pakistan and India [32,33], impact of COVID-19 on the Higher Education Commission [34], limited instructional strategies for online education [1], and challenges of online education for medical students [17].

The study in [31] recognized the effectiveness of online education in Lahore. A questionnaire was distributed to almost 240 students about the arrangement of online classes. According to the survey, the majority of students are adjusting to online education regarding COVID-19. The paper only suggested that the government should provide awareness to students regarding online education.

Developing countries such as Pakistan have been severely affected by COVID-19, especially in the education system. The government, especially educational institutions, was not ready for online education during this pandemic. The shift from traditional teaching to online teaching created many challenges for teachers and students. The studies in [34,35] highlighted the challenges of online education in Kenya and all around the world. However, the studies highlighted only the primary challenges of online education and did not explain them in detail. Therefore, the scope of these studies is minimal and does not cover the digital challenges, especially in detail.

These studies showed some post-effects of COVID-19 on the students but these post-effects need to be explained further [33,34,36]. Furthermore, some suggestions were made to continue online education but in a way that does not affect students' results or waste

their time. Unfortunately, the studies did not give suggestions for future pandemics or lockdowns, which are necessary for government institutions to be able to prepare for the best interests of the students and faculty.

The above-mentioned studies as shown in Table 1 discussed limited parameters of online education during COVID-19. A few of the studies were limited to an online survey but a few of them also implemented their models for the data collection. The models used in the previous method and this study are only for the collection of the data and their output. Similarly, the proposed model also collects and produces the output according to the collected data. However, many challenges of using the F model are highlighted along with possible solutions because it can assist with identifying the factors that affect the overall results and need improvement. Likewise, the studies mentioned above discussed the challenges during COVID-19, but this paper is not only limited to the COVID-19 scenario but to other viruses, diseases, or scenarios during which lockdowns could be implemented in the future. Therefore, this paper has a broader aim, that is, to prepare governments and educational institutions in developing countries, such as universities, schools, and colleges, for future lockdowns and to intervene effectively to mitigate the effects of lockdowns on educational institutions in some of the most deprived countries in the world.

Table 1. Comparison of methods.

Author/Year	Purpose	Proposed Methodology	Key Parameters
Shahzad et al. [29], 2020	Online learning during COVID-19	Convergent and parallel mix, method, and design and a survey.	Digital and technical parameters
Akram et al. [30], 2020	Digital education in Pakistan	A survey	Digital and technical parameters
Anwar et al. [31], 2020	The barriers and challenges faced by students in online education	A cross-sectional case study and a survey.	Digital, technical, and administrative parameters. Limited social parameters are also discussed.
Jena [32], 2021	Impact of COVID-19 on higher education in India	A survey	Digital and technical parameters
Rehman et al. [34], 2020	Challenges to online education in Pakistan during COVID-19	Systematic literature review	Digital, technical, and governmental parameters.
Faheem et al.	Factor model for online education	F model and a survey.	Digital, technical, general student, financial, and social parameters.

3. Methodology

The survey was conducted for universities in the southern district of Khyber Pakhtunkhwa, Pakistan. Here, the resources are very limited in terms of the internet, electricity, roads, infrastructure, etc. COVID-19 severely affected education in the years 2019–2021 in that region, and the data are collected only from the University of Science and Technology and the University of Lakki Marwat. All university faculty members and administration staff helped to disseminate the survey; however, only the research team was able to access the data. The research team was responsible for the collection and analysis of the data and the survey design.

The data from the survey are then used in the F model. Areas lacking attention from the government or universities or lacking parental or digital support are highlighted in the model. Through this model, the government, universities, and parents can minimize the risks to student health, finances, studies, online education, etc. All the procedures are shown in Figure 1.

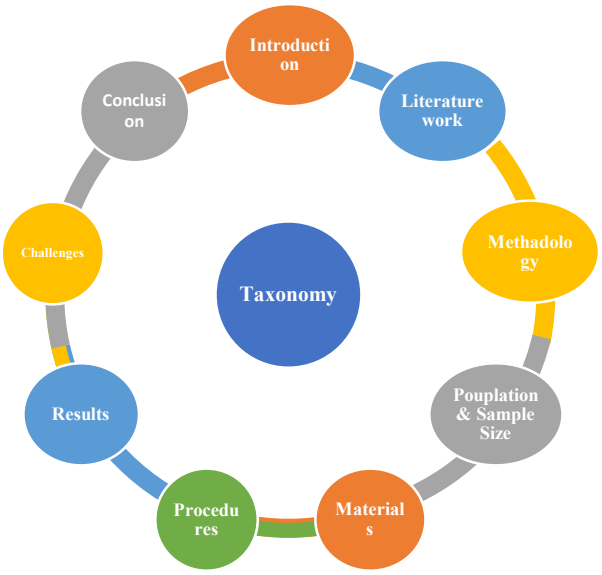

Figure 1. Taxonomy.

4. Population and Sample Size

The study was performed in two public sector universities in the southern district of Khyber Pakhtunkhwa, Pakistan. The number of students in these universities is 3200. It was not possible during the COVID-19 lockdown to collect data from all the students. Therefore, a sample of 800 students was drawn from the total population. A sample of 800 students was selected through a simple random sampling technique from the available population.

5. Materials

The survey was designed with separate questions/challenges for the students. Many of the challenges were similar but their responses were different. A total of 57 questions were formulated for the students. The questions related to students' courses, internet facilities, basic facilities, financial issues, technical issues, and health-related issues.

6. Procedures

The data collection began on 1 March 2020 and continued until 28 March 2020 and comprised two stages. In this survey, problems during COVID-19 related to the online education of poor students, middle-class students, and rich students were discussed. All these students live in remote areas of Pakistan where there are no primary facilities such as internet, electricity, etc., and where available, they are inadequate for online classes due to low-quality bandwidth. The first stage was divided into primary and secondary stages. As discussed earlier, this survey was conducted in two universities including the University of Lakki Marwat. In the primary stage, the survey was completed at the University of Lakki Marwat to avoid ambiguity and errors. Students completed a survey about the challenges during online classes. In addition, they were asked about difficulties with any of the questions in the survey. In the secondary stage, the survey list was emailed to the respective departments of the other two universities and the teachers were instructed to liaise with their students in case of any difficulties completing the proforma. Finally, the faculty members fully cooperated with the students during the filling of the proforma to obtain unbiased results and to highlight the issues the students were facing in online classes during COVID-19.

7. Proposed Model

In this paper, an F model is designed for the evaluation and performance of each factor. It is very useful in evaluating the performance of a particular organization and the factors involved in conducting a survey, as well as the factors involving scientific labs, wireless

networking [20,37], mobile ad hoc networks [21,22], the Internet of Things (IoT) [23], sensor networking, improvements in each sector of the organization, and much more.

$$A = \sum [\![(Ai \ldots\ldots An)/Am \times 100]\!] \quad (1)$$

In Equation (1), Ai represents a factor, and the factors can be increased up to An. Likewise, Am represents the total number of factors.

$$B = \sum (Bi \ldots\ldots Bn)/Bm \times 100 \quad (2)$$

$$C = \sum (Ci \ldots\ldots Cn)/Cm \times 100 \quad (3)$$

$$D = \sum (Di \ldots\ldots Dn)/Dm \times 100 \quad (4)$$

$$Z = \sum (Zi \ldots\ldots Zn)/Zm \times 100 \quad (5)$$

All the equations are combined into Equation (6).

$$F = \sum [\![(Ai \ldots\ldots An)/Am \times 100]\!] + \sum (Bi \ldots\ldots Bn)/Bm \times 100 \ldots\ldots\ldots\ldots\ldots + \sum (Zi \ldots\ldots Zn)/Zm \times 100)/(Total\ factors) \quad (6)$$

This equation shows that all the factors are directly related and F represents the F model. Let us consider Equation (1); if any factors increase, then the overall effect of A will increase. Similarly, if any factor in the equation decreases, then the overall effect of A will decrease. The scenario will be the same for Factor B and so on up until Factor Z. Equation (6) shows that the factors are directly related to each other.

Table 2 contains 57 factors and is divided into 4 sections, i.e., A (digital and technical challenges), B (general challenges), C (financial and lack of support challenges), and D (SOP challenges), all based on the same characteristics. Table 2 is further divided into poor students, average students, and rich students, and each section is divided into three columns, i.e., yes, no, and yes but not effective.

In section A, the results for the 18 items for poor students, average students, and rich students are very discouraging. If universities and the government facilitate students in those specific areas, then the factor percentage will improve, and hence the performance of online education in terms of digital and technical challenges will also improve. Likewise, the relationships between employees and decision makers in organizations can be strengthened using the F model, which improves the performance of the organization.

Figure 2 shows that A, B, C, D, and E are different factors in this model, and their combined results will be accumulated as factor F. As shown in the results, the F factor of students is 18. The F model will first show the values of the different factors but this depends on the priorities of an organization, i.e., which factors it wants to improve and what percentages are given to certain factors. As the current paper is related to online education, all the factors are equally distributed. To increase the F factor, the government and the educational institution need to improve the facilities for the students and teachers, as shown in Table 2, which will automatically increase the F factor. This model is ideal as it compares the performances of different departments in an educational organization in order to improve performance (related to the staff and products) in these departments, which addresses the deficiencies identified in some surveys and case studies. This model provides independence to the organization by selecting specific factors that are decreasing the performance of the organization and its employees. As a result, targeting specific factors will increase the F model's percentage. The F model can also show good performance in the sensor network, wired network, mobile ad hoc network, and internet of things, where all the factors are directly related to each other.

Table 2. Data collection of students.

S.no	Variable	For Poor Students			For Middle Class Students			For Rich Students		
		Y	N	YNG	Y	N	YNG	Y	N	YNG
A	**Digital and Technical Challenges**									
1	Availability of secure internet	… …	100%	… …	… …	100%	… …	… …	100%	… …
2	Availability of internet facilities by PTCL	15%	61%	24%	18%	52%	30%	22%	46%	32%
3	Standard internet facilities provided by PTCL are suitable for online classes	… …	100%	… …	… …	100%	… …	… …	100%	… …
4	Availability of internet facilities provided by private cellular companies	100%	… …	… …	100%	… …	… …	100%	… …	… …
5	Standard internet facilities provided by private cellular companies are suitable for online classes	… …	100%	… …	… …	100%	… …	… …	100%	… …
6	Awareness of the use of mobiles, tablets, and laptops	29%	71%	… …	41%	51%	… …	100%	… …	… …
7	Effectiveness of online exams	41%	59%	… …	55%	45%	… …	68%	20%	12%
8	Benefits of PERN	22%	9%	69%	35%	11%	44%	40%	35%	22%
9	Benefits of LMS	20%	11%	69%	38%	14%	48%	55%	25%	20%
10	Benefits of synchronous mode (Zoom, Google Classroom, Hangouts)	20%	11%	69%	38%	14%	48%	52%	28%	20%
11	Benefits of asynchronous mode	29%	11%	60%	69%	11%	20%	81%	3%	16%
12	Benefits of pre-recorded videos (YouTube)	… …	100%	… …	… …	100%	… …	… …	100%	… …
13	Awareness of online education applications	9%	80%	11%	20%	71%	9%	23%	65%	12%
14	Classes are not according to timetables	… …	100%	… …	… …	100%	… …	… …	100%	… …
15	Electricity facilities	… …	… …	100%	… …	… …	100%	… …	… …	100%
16	Backup facilities	… …	100%	… …	… …	100%	… …	… …	100%	… …
17	Broadcasting facilities	… …	100%	… …	… …	100%	… …	… …	100%	… …
18	Confusion between synchronous and asynchronous education	45%	16%	39%	42%	19%	41%	38%	23%	39%
B	**General Challenges**									
19	Level of interest by 1st and 2nd semester students	8%	88%	4%	5%	90%	5%	5%	91%	4%
20	Level of interest by 3rd semester and senior students	22%	44%	34%	69%	21%	10%	87%	9%	4%
21	Non-satisfaction of female students during videos	65%	35%	… …	63%	37%	… …	62%	38%	… …
22	Interest by students having weak educational background at college level	11%	85%	4%	5%	90%	5%	5%	91%	4%
23	Interaction with teachers	41%	17%	43%	39%	20%	41%	44%	21%	35%
24	Training of students	… …	100%	… …	… …	100%	… …	… …	100%	… …
25	Performance of good students	10%	81%	11%	65%	26%	9%	91%	4%	5%
26	Extra stress experienced by female students	88%	8%	6%	83%	8%	9%	79%	17%	4%
27	Group discussion is completely stopped	100%	… …	… …	100%	… …	… …	100%	… …	… …
28	Combined study is completely stopped	100%	… …	… …	100%	… …	… …	100%	… …	… …
29	Gatherings of friends are banned	100%	… …	… …	100%	… …	… …	100%	… …	… …
30	Social media use increased	61%	39%	… …	67%	33%	… …	62%	38%	… …
31	Changes in negative behavior of students due to long stays at home	45%	55%	… …	57%	43%	… …	69%	31%	… …
32	Community gatherings are forbidden	… …	100%	… …	… …	100%	… …	… …	100%	… …

Table 2. *Cont.*

S.no	Variable	For Poor Students			For Middle Class Students			For Rich Students		
		Y	N	YNG	Y	N	YNG	Y	N	YNG
A	**Digital and Technical Challenges**									
33	Recreation places are closed	… …	100%	… …	… …	100%	… …	… …	100%	… …
34	Sporting grounds are closed	… …	100%	… …	… …	100%	… …	… …	100%	… …
35	Hostels are closed	… …	100%	… …	… …	100%	… …	… …	100%	… …
36	Away from the books	… …	100%	… …	… …	100%	… …	… …	100%	… …
C	**Financial Challenges and Lack of Support**									
37	Lack of support from the institution	… …	100%	… …	… …	100%	… …	… …	100%	… …
38	Lack of support from the government	… …	100%	… …	… …	100%	… …	… …	100%	… …
39	Educational and research visits are forbidden	100%	… …	… …	100%	… …	… …	100%	… …	… …
40	Uncertainty and fear of adopting online classes and exams	43%	15%	42%	39%	20%	41%	39%	25%	36%
41	Negative impact on research	87%	7%	6%	85%	9%	6%	80%	17%	3%
42	Laboratory access	… …	100%	… …	… …	100%	… …	… …	100%	… …
43	Access of arts and designing students to their instruments	… …	100%	… …	… …	100%	… …	… …	100%	… …
44	Experimentation is completely stopped	… …	100%	… …	… …	100%	… …	… …	100%	… …
45	Less interest of students due to long duration of COVID-19	82%	8%	10%	83%	7%	10%	77%	17%	6%
46	Lack of parental support	81%	9%	10%	47%	33%	20%	… …	100%	… …
47	Lack of family support	91%	4%	5%	56%	25%	19%	… …	100%	… …
48	Lack of societal support	100%	… …	… …	100%	… …	… …	52%	19%	29%
49	Loss of internships	100%	… …	… …	100%	… …	… …	100%	… …	… …
50	Loss of part-time jobs	… …	100%	… …	… …	100%	… …	… …	100%	… …
51	Students' debt crises	… …	100%	… …	74%	20%	6%	100%	… …	… …
D	**SOPs Challenge**									
52	Irregularities in SOPs during COVID-19	95%	2%	3%	91%	4%	5%	92%	3%	5%
53	Virus spreading among students	9%	4%	6%	89%	5%	6%	91%	5%	4%
54	Handwashing, sanitizers, and masks are not used	92%	6%	5%	87%	9%	4%	79%	9%	11%
55	Impact on student health	91%	4%	5%	85%	11%	4%	81%	11%	9%
56	Psychological reaction	45%	40%	15%	22%	69%	9%	25%	65%	12%
57	Laziness	88%	4%	8%	86%	11%	6%	82%	11%	7%

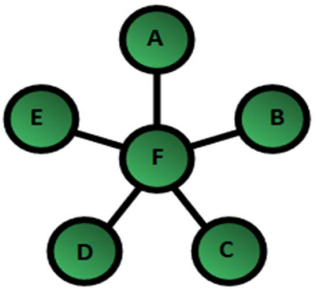

Figure 2. F Model.

8. Results

In this paper, a survey is conducted on the following variables, which are considered challenges. These variables are divided into digital and technical challenges, general challenges, financial challenges, and SOPs during COVID-19. All the variables are self-defined, but a few variables need explanations that are discussed below.

First, the digital challenges are discussed. In developing countries such as Pakistan, cybersecurity and network security are negligible, and even a bachelor's student can hack the data of any device. The Internet in Pakistan is provided by either the government, i.e., Pakistan Telecommunication Company Limited (PTCL), or private cellular companies. PTCL is trying its best to provide the Internet to people, but it is not reliable for online classes due to a frequent loss of connection, slowing of the Internet, unavailability of fiberoptic cable, and software and hardware issues. In the case of software and hardware issues, the complaint is usually handled within a week or longer, which wastes students' time. Such services provided by PTCL are only available for people living in cities; however, in rural areas, the situation is even worse with a very limited bandwidth of 4 Mbps, and PTCL does not even service 90% of rural areas. The same situation occurs with private cellular companies. However, their networks are active all over Pakistan, although their internet speed is very limited in rural areas, and online classes or video conferencing are almost impossible, which affects the students of Pakistan. In addition, the internet packages provided by private cellular companies are costly. In rural areas, the Internet services provided by PTCL or private cellular companies are unreliable and hence are not practical. According to the World Bank report, only 71.5% of people in Pakistan have access to electricity. Hence, 28.5% of people do not have access to electricity. Furthermore, there is load shedding of 6 h a day in big cities, and in rural areas, the load shedding can last from 12 to 18 h a day. 80% of the students do not have backup facilities in case of load shedding because people are very poor in the southern part of Pakistan, and during COVID-19, the poverty level rose to 40%, and if lower middle class and middle class are included, then the percentage is more likely to be 80% [38].

In cities, most students who belong to middle-class and rich families are aware of using and applying digital devices such as laptops, mobile, and tablets. However, students in rural areas do not have access to digital devices and nor do they know about applications related to online classes. Therefore, the students in these communities are the real losers in the COVID-19 pandemic in relation to online classes and online exams.

The Pakistan Education and Research Network (PERN) connects universities and research institutes through high-speed internet for the requirements of research and education both inside and outside the country. The PERN is a high-speed internet connection, but the end-user has limited bandwidth and the flow between the PERN and the end-user is tightly controlled. Hence, the PERN is not useful in developing countries, nor is the high-bandwidth LMS that is offered. On the other hand, in asynchronous mode, pre-recorded videos and video recordings are beneficial in the case of an unreliable internet connection. Most students do not have a smartphone, tablet, or laptop and, therefore, they are not in touch with online education, nor are they able to adjust to the timing of online classes. Although the HEC provided PKR 10 million in funds to universities during the COVID-19 pandemic, unfortunately, that money has not been used to improve internet facilities and online classes. Furthermore, only the virtual university has a channel for broadcasting and other universities do not provide this facility.

Student interest in online classes is greater among third-semester and senior students, and this interest is significantly lower among first- and second-semester students. Senior students are more friendly with their teachers and used to the university environment than newer students who have had no interactions with their teachers at all. During online classes, they are very hesitant to ask questions and seem confused about digital applications and devices. This hesitation toward the use of technology severely affects students with a weak educational background. As a result, there is a decrease in student attendance.

Intelligent students with weak financial backgrounds do not have a smartphone or a laptop, which affects their performance.

In Islamic society, female students are exposed to many problems, especially veiling, and then in a fundamentalist Islamic country such as Pakistan, females do not talk or make friends with their male classmates. In online classes, male students often make whistling or hooting noises or even send messages through applications such as Google Meet. This discourages female students from participating in presentations, group discussions, and group study. The laboratories have been closed, which has severely affected experiments and research. Access to labs/instruments of arts and design students has also been restricted, and all related activities were halted during the COVID-19 pandemic. Due to the lack of training and preparation for online classes and the confusion around synchronous and asynchronous education, student interest in online classes has been very low.

The COVID-19 pandemic has severely affected students' social lives due to restrictions on friend gatherings, community gatherings, recreation places, sporting grounds, and hostels. This has caused an increase in the use of social media and has changed the behavior of the students. In addition, students have had no access to the university library during lockdowns, which has ultimately increased the distance between the students and the learning materials. Furthermore, collaborations between students and administrative staff have been very limited.

Due to COVID-19, students have lost their jobs and internships, which has increased their debts. Low family incomes and the lack of family, parental, and social support further deteriorate the debt crises. Moreover, in developing countries, due to the lack of education and awareness among students of COVID-19, parents and society, in general, do not follow the SOPs related to COVID-19, nor are they careful with handwashing, hand sanitizing, and wearing masks. As a result, the disease has had a terrible impact on student health, psychology, motivation, and attendance in online classes.

Y = Yes = good, increase N = No = bad, decrease

YNG = Yes but not Good/available/functioning/working/active

For simplicity, the survey in Table 2 is divided into digital challenges, general challenges, challenges related to finances and government support, and SOP challenges. It is further divided into poor, middle-class, and rich students. The data on poor students are first discussed and inserted into Equation 1. All the data are inserted into the F model with the four main factors labeled A, B, C, and D. For the digital challenges, there are 18 sub-factors that are inserted into Equation A. It should be noted that only those data that need improvements are inserted, but for a better understanding, all the values are inserted into Equation (A).

$$A = \sum \frac{Ai + Bi + Ci \ldots\ldots Ri}{18} \times 100$$

$$A = \sum \frac{0 + 0.61 + 0 + 1 + 0 + 0.29 + 0.41 + 0.22 + 20 + 0.20 + 0.29 + 1 + 0.09 + 0 + 0 + 0 + 0 + 0.45}{18} \times 100$$

$$A = 26.4\%$$

Similarly, 18 sub-factors are inserted into Equation (B)

$$B = \sum \frac{0.08 + 0.22 + 0.65 + 0.11 + 0.41 + 0 + 0.10 + 0.88 + 0 + 0 + 0 + 0.39 + 0.55 + 0 + 0 + 0 + 0 + 0}{18} \times 100$$

$$B = 18.83\%$$

Similarly, 15 sub-factors are inserted into Equation (C)

$$C = \sum \frac{0 + 0 + 0 + 0.15 + 0.07 + 0 + 0 + 0 + 0.08 + 0.09 + 0.04 + 0 + 0 + 0 + 0}{15} \times 100$$

$$C = 2.8\%$$

Similarly, 6 sub-factors are inserted into Equation (D)

$$D = \sum \frac{0.02 + 0.04 + 0.03 + 0.04 + 0.4 + 0.04}{6} \times 100$$

$$D = 9.5\%$$

Insert A, B, C, and D into Equation (6)

$$\mathrm{F} = \frac{26.4 + 18.83 + 2.8 + 9.5}{4}$$

$$\mathrm{F} = 14.3825$$

This shows the F model for poor students.
Now, insert the data of middle-class students into the F model

$$A = \sum \frac{0 + 0.18 + 0 + 1 + 0 + 0.41 + 0.55 + 0.35 + 0.38 + 0.38 + 0.69 + 1 + 0.20 + 0 + 0 + 0.59 + 0 + 0.42}{Am} \times 100$$

$$A = 32\%$$

$$B = \sum \frac{0.05 + 0.69 + 0.37 + 0.05 + 0.39 + 0 + 0.65 + 0.08 + 0 + 0 + 0 + 0.33 + 0.57 + 0 + 0 + 0 + 0 + 0}{18} \times 100$$

$$B = 17.6\%$$

$$C = \sum \frac{0 + 0 + 0 + 0.20 + 0.09 + 0 + 0 + 0 + 0.07 + 0.33 + 0.25 + 0 + 0 + 0 + 0.20}{15} \times 100$$

$$C = 7.6\%$$

$$D = \sum \frac{0.04 + 0.05 + 0.09 + 0.11 + 0.69 + 0.11}{6} \times 100$$

$$D = 18.100\%$$

Insert A, B, C, and D into Equation (6)

$$\mathrm{F} = \frac{32 + 17.6 + 7.6 + 18.1}{4}$$

$$\mathrm{F} = 18.825$$

This shows the F model for middle-class students.
Now, insert the data of rich students into the F model

$$A = \sum \frac{0 + 0.22 + 0 + 1 + 0 + 1 + 0.68 + 0.4 + 0.55 + 0.52 + 0.81 + 1 + 0.23 + 0 + 0 + 1 + 0 + 0.38}{18} \times 100$$

$$A = 43.2\%$$

$$B = \sum \frac{0.05 + 1.87 + 0.38 + 0.05 + 0.44 + 0 + 0.91 + 0.17 + 0 + 0 + 0 + 0.38 + 0.31 + 0 + 0 + 0 + 0 + 0}{18} \times 100$$

$$B = 19.7\%$$

$$C = \sum \frac{0 + 0 + 0 + 0.25 + 0.17 + 0 + 0 + 0 + 0.17 + 1 + 1 + 0.19 + 0 + 0 + 1}{15} \times 100$$

$$C = 25.2\%$$

$$D = \sum \frac{0.04 + 0.05 + 0.09 + 0.11 + 0.65 + 0.11}{6} \times 100$$

$$D = 17.5\%$$

Insert A, B, C, and D into Equation (6)

$$\mathrm{F} = \frac{43.2 + 19.7 + 25.2 + 17.5}{4}$$

$$\mathrm{F} = 26.4$$

This shows the F model for rich students.

Figure 3 shows categories A, B, C, and D for poor, middle-class, and rich students. It can be seen that the overall satisfaction of students with online education is very low and even for rich students it is below 50 %, which is a very alarming figure. Similarly, middle-class and poor students are the most affected as they did not have access to the facilities needed for online education during the COVID-19 pandemic, and their performance, trust, and satisfaction are subsequently low compared to rich students.

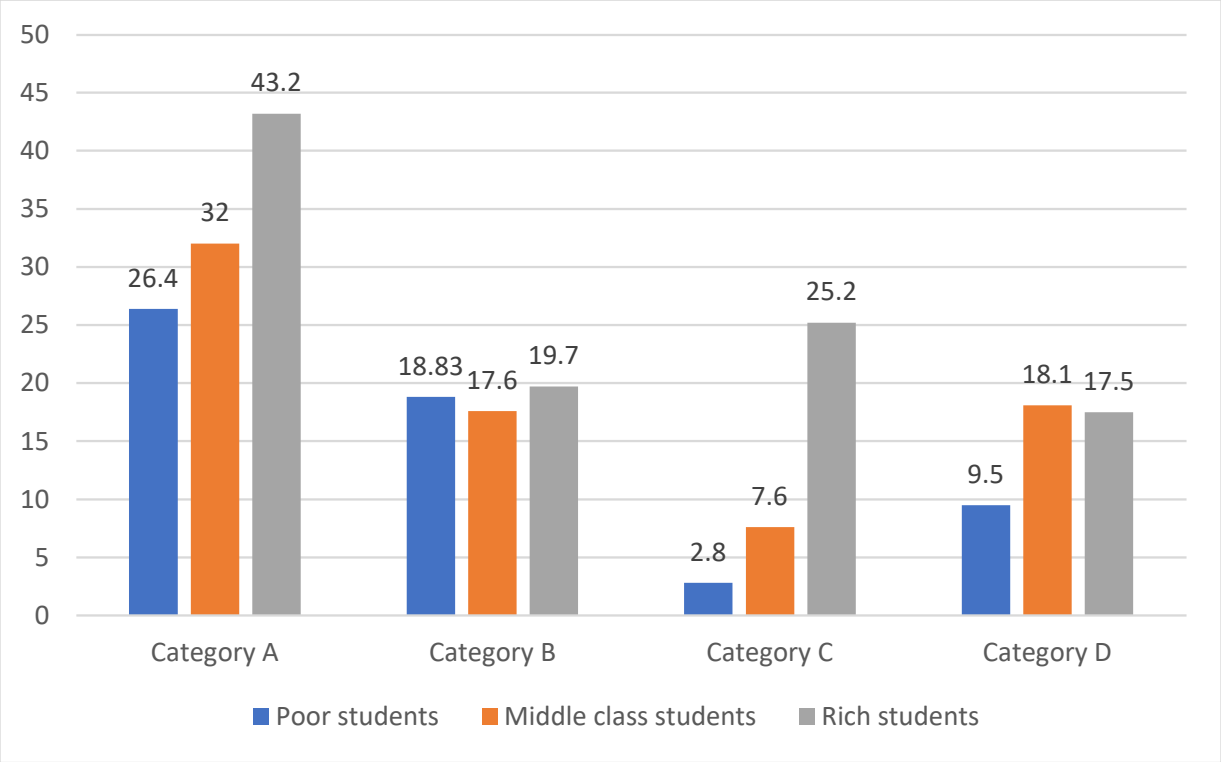

Figure 3. Category A, B, C, and D of F model for poor, middle-class, and rich students.

Figure 3 shows that we should improve the parameters and categories that are most affected and that they should be targeted for improvements, not only for the current COVID-19 situation but also for future pandemic situations. Figure 4 represents the F model for the overall parameters (57) and categories, and it the effects of COVID-19 on students can be easily seen.

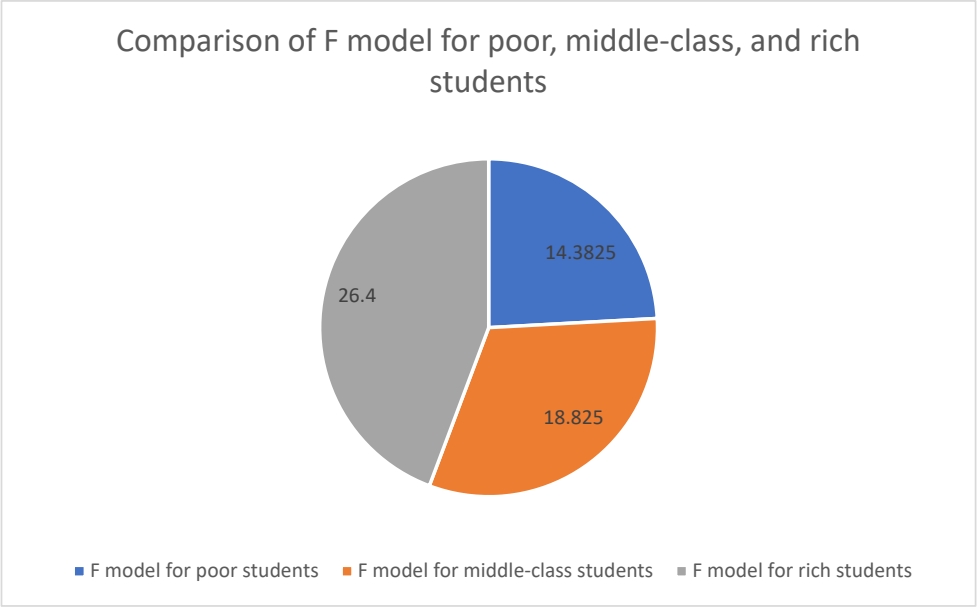

Figure 4. F model for poor, middle-class, and rich students.

9. Discussion and Future Directions

In this section, the results and future directions are discussed. This paper discusses the challenges faced by students in online education. The challenges can also be identified through a systematic literature review [39,40], which is a very lengthy and time-consuming process. However, the F model makes this process very simple and shows challenges such as a lack of training, lack of awareness of social media and privacy, financial problems, lack of government support, lack of university support, lack of family support, etc. The paper also describes technical problems such as a lack of digital devices, lack of or weak Internet connections, lack of IT support, lack of awareness of applications (e.g., Zoom, Google Classroom, Google Meet) and understanding of synchronous and asynchronous modes of learning, lack of electricity and backup facilities, and difficulties using PERN and the LMS. This paper also presented the social challenges faced by students during the pandemic including restrictions on student gatherings and community gatherings and restricted access to recreation places, sporting grounds, and hostels. Long stays at home change students' behavior, and due to excessive use of social media, they are not focused on their studies.. In addition, the lack of family, parental, and community support and the loss of internships and part-time jobs significantly impacts students' behavior and personalities. A significant social behavioral issue is also discussed in which the people of developing countries are not taking COVID-19 seriously and are not following the SOPs. Likewise, students and teachers are also showing carelessness regarding COVID-19 SOPs, on which institutions and the government should provide education through workshops and seminars, and if people do not adhere to the SOPs, law enforcement agencies should be involved.

All the factors are calculated through the F model and the results are very disappointing for the field of online education during COVID-19. The most affected students are poor students, where the F factor is only 14.3825, and the most satisfied students belong to rich families with an F factor of 26.4 because they are more prepared for online classes. The most alarming situation is that all these values are very low, and they should be near or above 50%. However, this paper aims to encourage the government and universities to try their best to solve the challenges for students and provide a stable online environment by solving the above-mentioned challenges and barriers.

However, as a result of the challenges faced during the COVID-19 pandemic, universities should prepare for the worst in the future and should develop broad mechanisms for implementing online education. These challenges should be solved and faced using the

combined efforts of students, teachers, universities, the government, and society. Moreover, the government and HEC need to plan policies, training, workshops, and guidelines for online education and the government should release specific funds to educational institutions for obtaining more resources in terms of technology. There are also some future directions which are outlined below.

9.1. Internet Facilities, Electricity, and Backup Facilities

The government should take immediate action to provide internet facilities in urban, rural, and remote areas with fiberoptic installations. With this type of large project, the government should request that private cellular companies provide standard internet services at cheaper rates during a pandemic. Developing countries should minimize load shedding in a pandemic situation. For backup facilities, the government should install solar power plants in universities, colleges, and schools.

9.2. Benefits of PERN and their LMS

The PERN uses a high-speed internet connection and works efficiently if students at home also have high-speed internet. To achieve this, students should be supported financially by universities or the government to access available internet packages offered by the government and private cellular companies. As a result, they could partake in online classes without any disruptions and could benefit from the PERN and their LMS.

9.3. Student/Teacher Training

Student and teacher training is necessary for online classes. Students and faculty members in developing countries have limited access to smart devices. Furthermore, they are not aware of applications such as Google Classroom, Google Meet, Zoom, etc. Likewise, workshops and seminars are important for educating about online classes to guide them about the synchronous and asynchronous modes of education, including pre-recorded videos, audio, video recordings, etc. This could motivate students to have more interest in online classes and decrease student absenteeism.

9.4. TV and Video Channels

All the universities should try their best to start a TV channel for broadcasting. Furthermore, the universities should have a YouTube channel on their official websites, and all the faculty members should upload their lectures so that students can watch video lectures in all subjects.

9.5. Access to Smart Devices

Students and teachers in this part of the world usually do not have smart devices. Therefore, the primary responsibility is to provide smart devices to the students. About 70% of students at The University of Lakki Marwat do not have smart devices, which could seriously affect their futures. Furthermore, the government should allow students and teachers to access free internet services during online classes, for example, during a pandemic. This will facilitate the students and their parents during challenging times.

9.6. Joint Cooperation between Doctors and the Community

During a pandemic such as COVID-19, everyone should be able to access the internet to obtain updated information about the prevention, precautions, and handling of the disease and the SOPs. Likewise, vaccination programs should be conducted through cooperation with a team of scientists and doctors. The solution to these socio-economic crises is possible through unity and a sense of community.

9.7. Self-Quarantine Application

The self-quarantine application is available in the Play store on every mobile device and confirmed or suspected cases of COVID-19 among students should self-quarantine. It

is now the government's responsibility to develop quarantine databases and quarantine medical centers through which confirmed or suspected COVID-19 cases should be tested, guided, and monitored. Furthermore, arrangements for COVID-19 testing should be made on day 1 and then the students should provide daily updates on their health conditions (e.g., cough, fever, etc.) through that application. If the health conditions are not stable, the student should be hospitalized, but if the health conditions are normal, the student should be tested again after 14 days. The Korean government implements this model.

9.8. Provision of Free COVID-19 Tests, Masks, Sanitizers, Gloves, and Thermometers to COVID-19-Affected Students

The government and universities should provide free COVID-19 tests for students because due to low incomes, the students cannot afford the tests, which is one of the reasons for the virus spreading in educational institutions. Similarly, students and teachers can benefit from the self-quarantine application if the government can provide masks, sanitizers, and gloves and transportation to COVID-19 centers, as well as a thermometer for the 14 day-duration of self-quarantine. The government should provide these because student-to-teacher ratios are lower in developing countries. If the government is not able to support students' expenses, then the universities should support the students with a predefined contribution from the government.

9.9. Training of Teachers and Students in COVID-19 Hazards

Proper training and awareness of the COVID-19 SOPs are needed for students and teachers. Students and teachers should be fully aware of proper guidelines on handwashing, the use of hand sanitizers and masks, the risks of shaking hands, and avoiding communal dining and gatherings, etc.

9.10. Awareness of Society about COVID-19 Hazards

Society plays a key role in the COVID-19 pandemic and should be made aware through community workshops and seminars run by well-known doctors and scientists. This will increase trust and society will cooperate better to fight against the pandemic.

9.11. Cooperation between Universities and Family Members to Ensure Students Follow the SOPs

If a student or teacher is affected by the disease, they should not be allowed on university premises by being notified through the noticeboard. Furthermore, during quarantine, universities should support students in their treatments. Moreover, students infected with the virus should be isolated from their families within their homes for the 14-day duration of quarantine as, unfortunately, people do not take the disease seriously.

9.12. Use of Artificial Intelligence

Advanced technologies such as artificial intelligence and the Internet of Things should be used to collect patient data, for example, geo-fencing for the proper tracking and monitoring of infected or quarantined patients should be used in the future.

9.13. Studying from Home

The culture of studying from home should be inspired by teachers. However, study time and family time should be balanced to preserve familial relationships. Similarly, the concept of searching for study materials on the internet should be introduced and encouraged by teachers. Therefore, students should be informed about the websites, video channels, and YouTube lectures where study materials are available online.

9.14. Concept of the Virtual Lab

During COVID-19, teachers attempted to teach the syllabuses, but it was not possible to successfully conduct lab work. This is a considerable loss for science students. The only solution is for the universities to conduct virtual labs. The virtual lab enables students to

work remotely with state-of-the-art million-dollar equipment. There is no requirement for students to acquire additional hardware or equipment. The labs can be accessed easily using laptops or smartphones and are an innovative and interactive way to explore science.

It is now the responsibility of universities to contact a company such as Labster, which can offer access to a fully advanced simulation-based lab at low prices. The universities can agree to a 6-month or 1-year contract. As a result, students can access these state-of-the-art labs, which are also accessed by the students of Harvard, California State University, Gwinnet Technical College, Stanford University, Exeter University, the University of New Haven, Trinity College, the University of New England, the University of Hong Kong, Berkeley, and many more. Medical students can also access Labster [26] for their labs and practical work.

10. Conclusions

In this paper, the challenges faced by students are discussed such as the lack of training, digital devices, and resources, as well as the financial issues and access to electricity, the Internet, and backup facilities. Such challenges should be addressed by universities, the HEC, and the government.

This paper shows the constraints currently experienced by universities and almost all university activities worldwide have been affected in one way or another. Universities cannot overcome all the challenges on their own but can minimize them through proper collaborations between the HEC, government, private sector, and society at large. Likewise, COVID-19 is a global pandemic and can be overcome with international collaboration at the global level leading to the local implementation of solutions. In this paper, almost all the challenges of online education are mentioned along with possible solutions. Now it becomes the responsibility of universities, the HEC, and the government to develop online education policies for higher education.

The data and results are calculated using the F model, which shows that developing countries need to do more for online education to protect the futures of students. This model can help the government to analyze improvements related to any given factor and can be used as a guideline for improving online education. The relevant institutions should take notice so that students in developing countries are able to complete their studies without wasting their time.

Author Contributions: Conceptualization, F.K.; methodology, F.K.; software, F.K.; validation, F.K., W.T. and I.T.; resources, W.T.; writing—original draft preparation, F.K.; writing—review and editing, F.K., W.T. and I.T.; project administration, W.T.; funding acquisition, W.T. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by the GRRC program of Gyeonggi province. [GRRCGachon2020(B04), Development of AI-based Healthcare Devices].

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

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

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