Article

Undergraduate Students' Device Preferences in the Transition to Online Learning

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Abstract: The global higher education sector has been greatly affected by the COVID-19 pandemic, and the mode of delivery has transformed into a blended learning mode of delivery or fully remote mode. Online delivery significantly demands reliable and stable internet access and technology, at both the lecturer's and students' ends. This paper investigates the challenges and barriers to accessibility of technologies used for remote delivery of learning and teaching. The paper also investigates key digital skills students need to help them develop and enhance their technology literacy. A survey was also conducted among 555 university undergraduate students to identify their choice of device to connect to remote learning during the transition to online learning. It was revealed that students used laptops and smartphones considerably and least relied on desktop computers. The results indicate the significance of a device's portability, built-in network hardware and cost. Further, it identifies the impacts of accessibility of educational technologies on students' learning experience.

Keywords: online learning; educational technologies; device use; digital skills; COVID-19

1. Introduction

The first trace of COVID-19 pandemic was detected in Wuhan, China, in December 2019 (Huang et al. 2020). This resulted in many countries having to embrace some form of lockdown, curfew or at least strict social distancing measures to prevent the spread of this contagious virus. Teaching and learning of students around the world had to move to an online mode of delivery to maintain the strict regulations of social distancing, and perhaps changed the higher education landscape for generations to come.

Before COVID-19, there were many universities where the delivery of learning and teaching had made use of online learning management systems, primarily for asynchronous learning. The lectures would be conducted physically and the lecturers used online learning management systems (virtual learning environments) such as Moodle and Blackboard to share lecture materials and resources with students. Concurrently, Massive Open Online Courses (MOOC) were also becoming popular as an e-learning modality through platforms like edX, Coursera, Udacity and FutureLearn (Valverde-Berrocoso et al. 2020; Tsironis et al. 2016). Assessment through online platforms was minimised compared to take-home assignments on many occasions. Online assessments were perceived as opening doors for a whole host of assessment violations, making it almost impossible for fair and uniform evaluation of students' performance. Therefore, in the majority of institutes, continuous assessments and examinations had been conducted in traditional physical settings before the pandemic. Further, to manage a course efficiently online it is essential to academics to know how to encourage students to learn independently, how to support and develop student self-discipline and planning, and how to manage timely assessment of student work including timely feedback (Almazova et al. 2020).

The pandemic forced educational institutes around the world to make a critical decision to either continue learning through online tools available or bring university activity

to an abrupt halt, which would have caused severe distress to students' education as well as economic viability of these institutes. For many institutes, the decision to transition rapidly to an online mode of learning had to be made in the backdrop of a wide "digital divide" within the society that existed before the pandemic.

Learning management systems have the capability to offer online students more personalised, flexible, portable, and on-demand experience (Komlenov et al. 2010). It gives students the opportunity to decide their learning pace and paths through the course content, while giving academics the opportunity to organise and modify the content in numerous ways to support a wide variety of individuals and groups (Araka et al. 2021). Additional resources can also be offered through learning management systems, for example, additional reading material or video content, which students can decide when to explore while taking as much as time they need. Also, some researchers identified Moodle as a tool to enhance learners' creative collaboration skills (Kim et al. 2019).

In the wake of the COVID-19 pandemic, non-traditional learning technologies with online learning platforms gained wider popularity. This is in the backdrop of more universities digitising their programmes due to the social-distancing and self-isolation restrictions. Therefore, it is imperative that higher education institutes make the full advantage of the technology and digital content available at a touch to make the programmes accessible to all students. Unfortunately, many institutions struggle to ensure digital accessibility to all students and the students may face a range of barriers when accessing digital content.

The present paper is organised as follows: firstly, the use of technology in learning/teaching are discussed. Then, the challenges and barriers to the accessibility of technologies are discussed with a focus on higher education. Additionally, impacts of accessibility of educational technologies on learning are discussed in the following section. Next, we present results of a survey conducted on undergraduate students from a wide range of backgrounds on their device use during the transition to online learning during COVID-19. Finally, we discuss the outcomes of the survey and conclusions are made based on the findings.

2. Use of Technology in Learning and Teaching Delivery

Online lectures can be easily customisable to students' needs, in that one can adapt to their own speed and study at one's own pace. There are reports of successful use of learning technology in a wide array of science- and engineering-based education before the pandemic (Vergara et al. 2017; Viegas et al. 2019) For example, a survey conducted among 222 medical and dental students in 2017 showed that 66% of students between years 2 and 4 said classroom-based learning should not be a mandatory component of their university education, suggesting an already-existing trend in the next generation of students' interest in non-traditional forms of learning and teaching such as learning management systems (LMS), laboratory videos, animations, computer simulations etc. (Daud et al. 2017).

Previous studies have highlighted the digital technologies that are regarded as most useful in students' university education. Firstly, learning management systems such as Moodle were popular among most students as a repository of lecture material. At the same time, learning management systems are powerful in providing a platform for students to engage in collaborative learning and problem solving, simulation-based learning, inquiry-based learning and to take many other innovative learning paths. Most universities are more frequently integrating simulation learning with collaborative problem solving (CPS) to enhance the student learning experience where significant impact can be seen in students' learning achievements (Komlenov et al. 2010; Araka et al. 2021).

Additionally, these platforms provided lecturers to illustrate concepts using videos, animation and images to be able to connect with students on a deeper level and to continue asynchronous discussions after face-to-face teaching. Then, the e-library database allows students to work remotely and research information for their study activities. It was found that lecture recordings were also useful to revise through replaying missed lectures or repeat viewing of content to improve one's understanding and to prepare for

examinations. Additionally, a range of social media, such as Facebook and WhatsApp, offered students platforms to exchange information and collaborate with fellow students (Henderson et al. 2017). Some researchers reported that Facebook has the potential to be used as an educational tool; however, its capabilities have only been used partially and contain many obstacles to be used (Manca and Ranieri 2013). Some of the obstacles are implicit institutional, teacher and student pedagogies and cultural issues.

In a previous study, participants outlined their concerns with using learning management systems such as the Moodle platform. The major criticisms are that: it is difficult to find resources in Moodle; lack of time for the platform; lack of need of Moodle. Among those who made use of the platform, the platform was commended for the layout of the course, such that it is easy to navigate; resources being up-to-date; regular feedback from the teacher and more time to complete the activities on Moodle (Parsons 2017).

As students adapt to the new remote learning environments, they will also have to develop digital resources and employ novel tools independently without much support from teachers or peers. Due to COVID-19, a rapid increase in dependency on technology-based education means that there is also a higher demand for a digitally skilled student population and workforce. There have been commendable efforts from the World Bank and other non-governmental organisations to raise students' digital competency by incorporating digital skills across subject curricula (Robinson Danielle and Rahima 2020). Teaching key digital skills is also becoming more difficult during the pandemic due to the widening of the "digital gap" (Jæger and Blaabæk 2020). Some researchers reported that COVID-19 has widened the educational gap in Latin America as it widens the inequality in access to digital devices and services (Basto-Aguirre et al. 2020).

For many years, technological advances in higher education have exclusively helped people with special needs (Badge et al. 2008; Dobransky and Hargittai 2006; Henry et al. 2014; Schur et al. 2005), elderly populations (Hanson 2001) and language learning students (Bax 2011). During the COVID-19 pandemic, these developed technologies were suddenly required to be expanded for all students in order to conduct remote teaching effectively and efficiently. It is recognised the concept of offering multiple options of learning as an effective way of facilitating inclusive teaching and learning practices with "multi-modal opportunities in terms of representation, engagement and expression" (Layer 2017).

Among students with disabilities, researchers found that many barriers to accessibility can be overcome through awareness of design issues, and that there is a need for practical advice for academics (Pearson and Koppi 2002). It was proposed to provide practical guidelines presented in a "user-friendly" manner for academics who want to deliver their lecture material online, then there is a need for the development of workshops to increase awareness of issues, techniques and tools in accessible design. A pivotal point for greater accessibility of online courses is to take a learner-centred design approach, one which takes account of the needs of the learner. Despite not being able to factor in all needs of each learner, reasonable steps must be taken to ensure the widest participation and to avoid discrimination of any kind (Pearson and Koppi 2002).

With steep competition, educational institutes are constantly on the lookout for new technologies that could deliver lecture content at a lower cost and reach out to the masses. In this quest, mobile phones have been tested out for more than a decade. Previous researchers have conducted a study to assess how mobile phones are being used in higher education for teaching and learning. It was discussed that there are security concerns with the advent of mobile phones but the popularity remains due to its ability to provide a mobile learning environment (Kim et al. 2006). Furthermore, some researchers showed students' perspectives on using mobile phones in higher education and it was mainly observed the effectiveness of using mobile devices under an informal mode of learning (Gikas and Grant 2013).

In developing countries, many students have struggled with limited accessibility to stable internet connections and reliable devices before the COVID-19 pandemic. Over the past 5 years, while there has been a significant evolution of new learning tools and

pedagogies in many developed countries, there has been improvement at a snail's pace in developing countries (Sife et al. 2007). This slowness to adapt to technological changes, due to attitude, low connectivity and resource deficiency, resulted in many direct and indirect impacts on students as well as educators.

Under the social-distancing and lockdown regulations, the internet gained an even greater role in supporting remote working, e-learning and online research collaborations, as highlighted by some researchers (Favale et al. 2020). This rapid shift has caused psychological distress among university and college students (Hanson 2001). Despite the promise of technology advantages, many students display a negative perception to online learning, which could also contribute to psychological stress. In the context of the COVID-19 pandemic, it was found that the students displayed a higher level of psychological anxiety due to e-learning crack-up during the pandemic (Hanson 2001). The results confirmed that the psychological distress was linked with the perception of e-learning crack-up and fear of academic year loss. Furthermore, the study found a positive correlation between fear of academic year loss and psychological distress.

It is not just the delivery of teaching, but the assessment of practical aspects of courses as well. Assessment is an essential component of teaching and learning as it allows to evaluate whether students' achievements align with the learning outcomes of individual courses as well as the overall programme. Although computer-based assessments are not a novel concept, it is rarely practised for concerns of validity, reliability and dishonesty (Khan and Jawaid 2020). However, the situation forced many examinations to be conducted virtually by adapting to open-book evaluations. It was reported that the mean score of test-takers increased for both multiple-choice questions (MCQ) and essay-based examinations, but, mean score lowered for short-answer examinations (Eurboonyanun et al. 2020). The study reported that students with lower GPAs (Grade Point Averages) may benefit more from the open-book format as students were able to perform better than their previous grade patterns (Eurboonyanun et al. 2020). Considering these trends, the researchers suggested that it may be necessary to recalculate passing scores based on a range of closed-book and open-book examinations. This would allow standardizing of the results among the students and provide a more reflective mark of the students' capability.

On the contrary, Imperial College London (UK) conducted online open-book examinations for final year medical students and found that the median mark for the open-book exams was equivalent to the median marks of the previous 3 years before the pandemic (Sam et al. 2020). The success of this was attributed to the nature of the questions, which have been said to focus on the application of knowledge rather than straightforward memorising, which did not provide an unfair edge over traditional modes of evaluation. Additionally, to detect and prevent possible examination violations, the Australian National University has developed software that can be installed on a candidate's computer, which has the capability to track eye movements, keystrokes and background noises (Evans 2020).

3. Challenges and Barriers to Accessibility of Technologies

Technology has already transformed the traditional learning and teaching environment, mostly in developed countries, but as a result of the COVID-19 pandemic, many other countries are also looking into ways of improving technology-enhanced learning opportunities for their students. Technology simplifies the learning process, where students no longer have to attend classes physically at a given time; instead, they can rely on technology and can be more independent learners.

A study was conducted at KTH Royal Institute of Technology (Sweden) to understand key barriers and drivers of technology-enhanced learning in higher education (Josefsson et al. 2018). It was revealed that the key barriers were unclear return on time investment, insufficient funding for purchases and lack of central decisions. On the other hand, key drivers were identified as collegial discussions, increased automatisation, technology-

enhanced learning support for the teachers, more tech-savvy students and greater engagement among the staff.

The relationship between organisational culture features and teachers' implementation of technology-enhanced learning was explored by another study. In this study, a survey was conducted among 684 teachers across six universities. In this study, seven dimensions of organisational culture were considered: goal orientation, participative decision making, innovation orientation, structured leadership, supportive leadership, shared vision and formal relationships. The study confirmed that the institution's culture influences teachers' perceived need, perceived usefulness, responsiveness and subsequently implementation of technology-enhanced innovation (Zhu 2015).

Recent studies continue to demonstrate deficiencies of using digital technologies in higher education for teaching and learning (Mercader and Gairín 2020). It was identified that the barriers can be broadly categorised into personal, professional, institutional, and contextual barriers; and it was found that professional barriers are the most prevalent and the discipline of arts and humanities was the field with the most challenging barriers. It was highlighted the importance of better professional development for teachers and greater involvement of the institution through strategic plans.

There is evidence of income inequality being more pronounced during the pandemic and playing a decisive role in students' education (Blundell et al. 2020). Some developing countries highlight problems related to accessibility to online education: the high cost of hardware, import tariffs, transmission costs, unstable and unreliability connectivity and bandwidth limitations (Nafukho 2007; Okiki 2011).

In addition to issues with digital infrastructure experienced in remote areas, there are also technical challenges when offering alternatives to face-to-face practical experiences to students in online teaching and delivery. It is generally well known that practice-based learning approaches (laboratory practicals, field exercises, workshops, etc.) are very difficult to implement in a socially distanced way for many science-based programmes. This is the case with most "hands-on" learning that is desired for engineering and technology-based programmes as well, where students expressing their creativity and problem-solving skills in a physical environment is an integral part of the programme. However, there are exceptions such as programming-oriented modules in engineering, where lecturers have used mobile apps and software to teach the subject.

The social distancing measures imposed by governments recommend that there is at least 1 or 2 m distance (depending on the policy of the country) maintained between people even while wearing a face covering. In most occasions, such a rule is difficult to be implemented in small laboratory spaces or in situations where the practicals need to be conducted in groups. This problem is further exacerbated by the difficulties most students reported with coming to the laboratory as the majority of the students relied on public transport, where the students are facing a bigger risk. These issues made organising laboratory sessions during the pandemic period nearly impossible. Therefore, in place of the physical laboratory practicals, many educators explored the potential of using recorded laboratory videos and computer simulations with varying success.

In the field of medicine, extensive digital tools have been used to replace hands-on learning, e.g., Anatomage table—an interactive screen allowing students to virtually dissect the human body and observe its structures (Remtulla 2020). Additionally, there are 3D computer models for dissection and prosection components of medicine as well as an interactive software called Touch Surgery, which can be used as a surgical simulation. Furthermore, live streaming of surgeries with cameras and wearable devices such as Snapchat glasses also allow students to take a close look into the surgical practice in the comfort of their homes. Virtual Reality (VR) is another rapidly developing tool for practical-based education in the fields of engineering, medicine and surgery. For example, VR technology has many benefits in engineering education, from the cognitive and pedagogical perspective, where it has the capability of replacing physical laboratories (Soliman et al. 2011). The use of VR technology minimises health and safety hazards, which is generally

a challenge needing addressing during physical engineering laboratories, and it also improves students' learning experience and knowledge (Valdez et al. 2014; Vergara et al. 2020). The VR technology has already been proven to be an effective support to doctors' training as doctors report a higher level of accuracy in their medical practice with the technology (Samadbeik et al. 2018).

Technology-enhanced learning significantly supports remote learning and teaching, but some of the barriers and challenges discussed above greatly depend on the circumstance of individual students who are part of the learning process. For example, for individual students to access technology-enhanced learning, they must have a device to connect to remote learning. The strength of the challenge becomes even stronger in the case of students who are studying in a developing country. In this paper, we are studying this challenge more in depth and evaluate student choice of device to connect to remote learning during the transition to online learning.

4. Materials and Methods

4.1. Details of the Survey

An online questionnaire was conducted among 555 university undergraduate students in Sri Lanka Technological Campus in Padukka, Sri Lanka, to investigate the device(s) they used to engage in online education during the transition from physical to remote learning. This questionnaire was administered using the Lime Survey platform, using multiple-choice questions. For these students, as well as for the majority of the lecturers, this was the first time that they fully engaged in online education without any reliance on physical modes of delivery. However, before the pandemic, the distribution of lecture materials, assignments and tutorials were carried out through the learning management system Moodle.

In the present survey, the students were from diverse backgrounds: engineering (286: 215 male and 71 female), technology (79: 51 male and 28 female), business (117: 50 male and 67 female), information technology (52: 39 male and 13 female) and music (21: 12 male and 9 female) as shown in Figure 1. The students were from a mixture of ages and at various levels in their study.
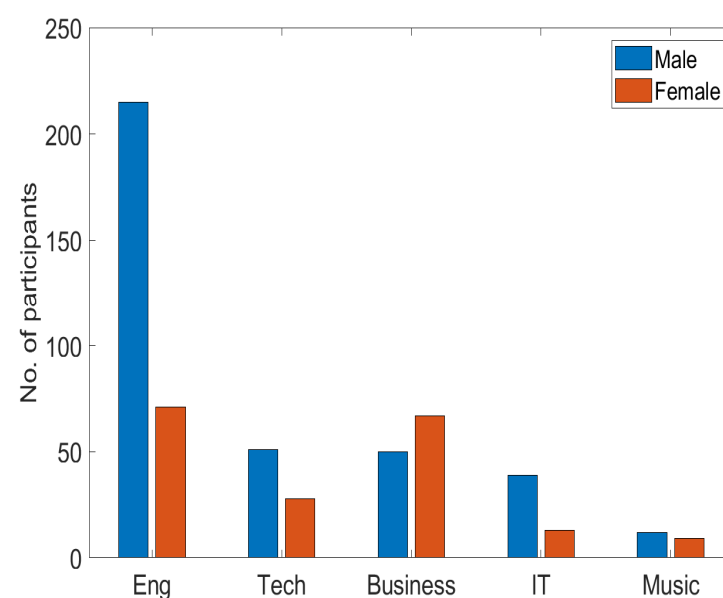

**Figure 1.** The distribution of participants among 5 different schools in the collected data sample.

The survey results from each school were analysed for the devices used during the transition phase. The results also present an analysis of device usage pattern by male and female students during the same period.

4.2. Discussion on Devices Used in Each School

The Engineering School showed that the most popular combination of devices for remote learning was laptop and smartphone (45%), followed by laptop only (34%) and smartphone only (8%), as shown in Figure 2a. The high percentage of laptop and smartphone combination could indicate a greater dependency on mobile internet (using hotspot technology) connections to access the internet in rural parts of the country. This allows students to move around with a device. Also, the results highlight the significant percentage of students who only relied on smartphones for their education, which would have posed difficulties when attending online lectures or viewing pre-recorded lecture videos and lecture material. Additionally, we also looked at the devices they used in their studies. In Figure 3a, it can be seen that 55% used laptop computers, 38% used mobile smartphones and only 6% used desktop computers.
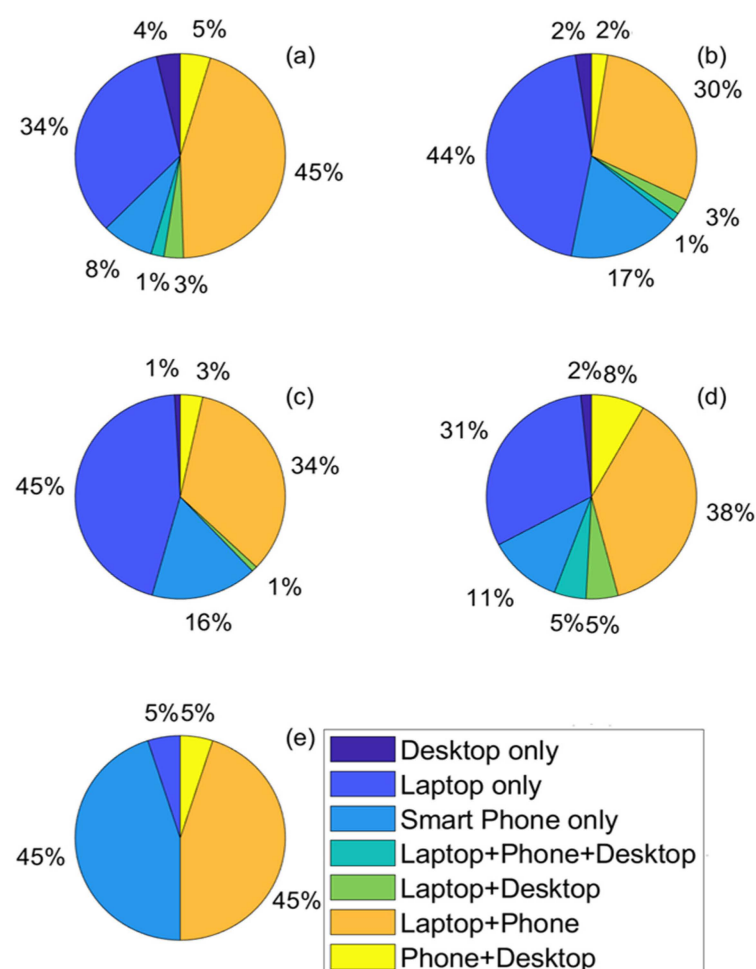
Figure 2. Device combinations used by students in Schools: (**a**) Engineering, (**b**) Technology, (**c**) Business (**d**), IT and (**e**) Music. Note: percentage shown in each figure is rounded to nearest whole number and hence the total may or may not be equal to 100%.
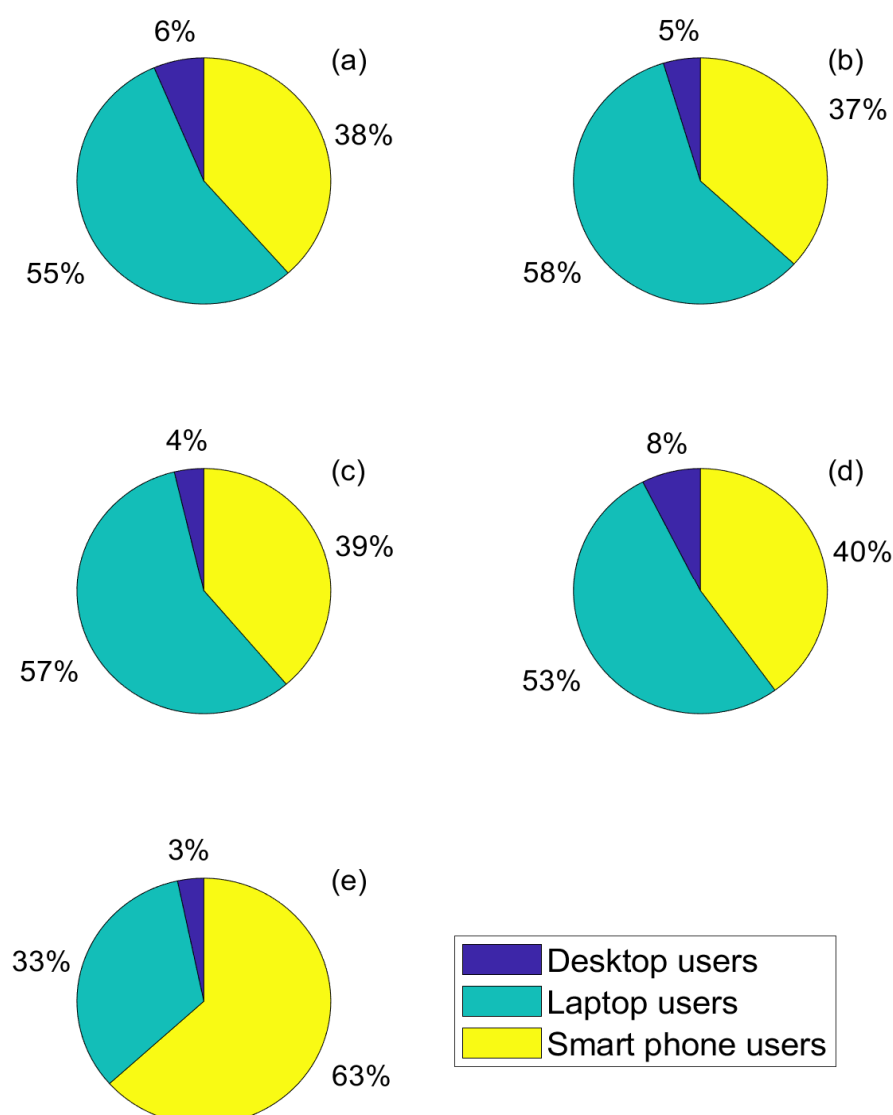
Figure 3. Devices used by students in Schools: (**a**) Engineering, (**b**) Technology, (**c**) Business, (**d**) IT and (**e**) Music. Note, percentage shown in each figure is rounded to nearest whole number and hence the total may or may not be equal to 100%.

The students from the Technology School showed that their choices of device combinations for remote learning were in the order of laptop only (44%), laptop and smartphone (30%) and smartphone only (17%), as shown in Figure 2b. It must be noted that the patterns of device use are found to be similar across the engineering and the technology schools. In the combinations used, it could be observed that the students studying technology relied more on smartphone only (17%) than their counterparts in the engineering school (8%). Further, users who only relied on a laptop to attend lectures increased in the Technology School, but those who used a laptop–smart phone combination decreased to 30%. Overall, Figure 3b shows that the students used laptop computers (58%), smartphones (37%) and desktop computers (5%), drawing parallels with the engineering students.

The students from the Business School said they are connecting to online education using a laptop only (45%), a laptop and phone combination (34%) and smartphone only (16%), as shown in Figure 2c. The accessibility to devices has not changed significantly between the students in the Business School and those in the Engineering/Technology Schools. This is further backed up by individual device use shown in Figure 3c: laptop computers (57%), smartphones (39%) and desktop computers (4%).

The results showed that the students from the IT School opted to use the combinations of laptop and smartphone (38%), laptop only (31%) and smartphone only (11%) in this order, as shown in Figure 2d. The overall device analysis in Figure 3d showed that students depended on laptop computers (53%), smartphones (40%) and desktop computers (8%).

The students in music school said they relied on the combined use of laptop and phone (45%), smartphone only (45%) and laptop only (5%), as shown in Figure 2e. It was interesting to highlight that, in the data sample, there were no students who only used a desktop to access online music education. In the Music School, shown in Figure 3e, it can be clearly seen that the smartphone was the most popular device, with 63% saying they use a smartphone device during this transition period for remote learning. This is followed by laptop (33%), and the least preferred option is indicated as a desktop computer (3%). This is perhaps indicative of the practical nature of music education. A music lesson conducted virtually would require a stable internet connection as well as access to a microphone and speakers. As a device, smartphones provide the most affordable option with built-in WiFi/4G as well as microphone and speaker hardware. On the other hand, the nature of the programme also suggests why a desktop computer is not highly regarded in this venture.

Overall, the results showed that the students' choices of device for online learning are in the following order: (1) laptop computer, 58% to 33%; (2) smartphone, 63% to 37%; and, at last, (3) desktop computer, 8% to 3%, as shown in Figure 3. The devices that have built-in hardware to access wireless internet were the popular choices among students. From the device combinations preferred, the laptop–smartphone combination was most consistently popular across schools, 45% to 30% of the sample, then laptop alone between 45% and 5%, mobile phone alone between 45% and 8%.

It is also important to note the unpopularity of the desktop computer across schools: individually, it was used only by 5% and in combination with other devices, its use was always less than 5%. There are many reasons for the unpopularity of a desktop computer. Firstly, the national lockdown due to COVID-19 was sudden with little time spared for students to return home from campus or off-campus accommodation. A bulky immobile computer is not favourable to use in this scenario. Additionally, as mentioned earlier, setting up wireless internet to a desktop can be expensive and especially difficult during a nation-wide lockdown when accessing these devices becomes even more difficult. The use of desktop computers is further discouraged by the frequent power failures prominent in rural areas; desktop computers are not a popular choice as they do not contain built-in batteries compared to the other devices.

At the same time, it is important to note the popularity of smartphones across schools for attending online lectures during the lockdown. Smartphones were arguably the most portable of the available devices due to their size, being lightweight, a generally long-lasting battery and providing easy access to the internet with built-in 4G and WiFi hardware. This meant that during the lockdown, with low preparedness, mobile phones could have proved to be the most versatile tools to access online lectures and keep up-to-date with learning. The results of the present survey could be comparable to higher education institutes in other developing countries where students are affected by low network coverage and deficiency of computer devices resulting in a "digital divide".

4.3. Comparison of Devices Used by Male and Female Students

From the Engineering School, the male students reported that they use laptop only (39%), a laptop–smartphone combination (36%), followed by smartphone only (11%), as shown in Figure 4a. Further, when the individual devices are analysed in Figure 5a, it was revealed that 56% use laptops, 37% use smartphones and 7% use desktop computers. Among the female students, these trends were found to be similar with 41% using a laptop–smartphone combination, 36% using laptop only and 12% using smartphone only, as shown in Figure 4a. Further, the female students were found to rely on the same devices at similar ratios, as shown in Figure 5a.
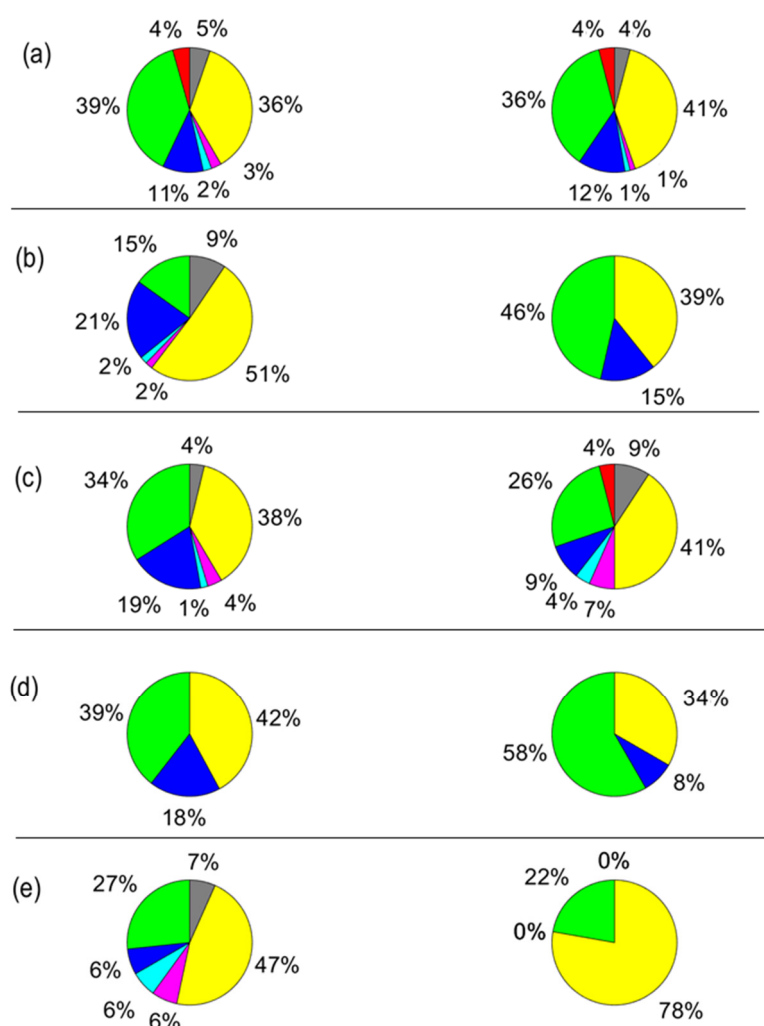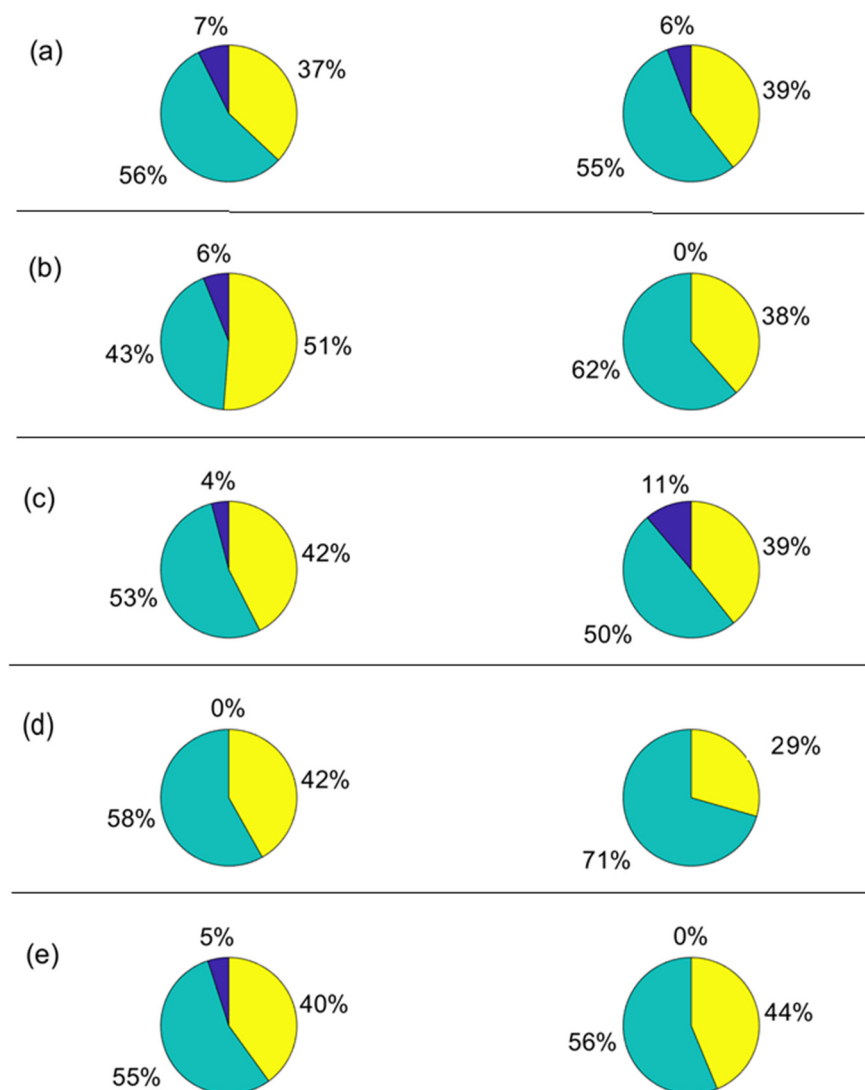
Figure 4. Device combinations used by male (left column) and female (right column) students in the schools: (**a**) Engineering, (**b**) Technology, (**c**) Business, (**d**) IT and (**e**) Music. Legend: green is laptop only, blue is smart phone only, red is desktop only, yellow is laptop+phone combination, cyan is laptop+phone+desktop combination, magenta is laptop+desktop combination, grey is phone+desktop. Note, percentage shown in each figure is rounded to nearest whole number and hence the total may or maynot be equal to 100%.

Among male students in the Technology School, as shown in Figure 4b, it was observed that the students relied on a laptop–smartphone combination (51%), smartphone only (21%) and laptop only (15%). Further, it was reported that 51% use smartphones, 43% laptop computers and 6% desktop computers in Figure 5b. Among the female counterpart, there were some key differences in device use. The female students reported that 46% use laptop only, 39% use a laptop–smartphone combination and 14% use smartphone only, as shown in Figure 4b. Then, it was reported that the female students' device use spread between 62% laptop computers and 38% smartphone devices. It is important to highlight that the female students reported using the laptop significantly more and have indicated no dependence at all on the desktop computer, as shown in Figure 5b.

In the Business School, male students reported that they used a laptop–smartphone combination (38%), laptop only (34%) and smartphone only (19%). Further, Figure 5c shows that the students relied on laptops (53%), smartphones (42%) and desktop computers (4%) for their studies. Among female students in the same school, the reported device use trends were similar: laptop–smartphone combination (41%), laptop only (26%), and smartphone only (9%), as shown in Figure 4c. Then, it was observed that female students' device use

spread among laptop 50%, smartphone 39% and desktop 11%, suggesting that more female students used desktop computers compared to their male counterpart (Figure 5c).

Figure 5. Devices used by male (left column) and female (right column) students in the schools: (**a**) Engineering, (**b**) Technology, (**c**) Business, (**d**) IT and (**e**) Music. Legend: blue is desktop users, green is laptop users and yellow is smart phone users. Note: percentage shown in each figure is rounded to nearest whole number and hence the total may or maynot be equal to 100%.

In the IT School, male students said they used a laptop–smartphone combination (42%), laptop only (39%) and smartphone (18%), as shown in Figure 4d. Further, Figure 5d indicated that the device use is between laptops (58%) and smartphones (42%). Among the female students, the clear choice was the laptop only (58%), followed by a laptop–smartphone combination (33%) and smartphone only (8%), as shown in Figure 4d. Further, it was also observed that only two devices were used: laptop computer (71%) overwhelmingly popular, followed by the smartphone (29%), as shown in Figure 5d.

In the Music School, male students reported to be using mainly the combinations of laptop–smartphone (47%) and laptop only (27%), as shown in Figure 4e. At the same time, Figure 5e showed that the device use is spread over three devices laptops (55%), smartphones (40%) and desktop computers (5%). Among female students, it was reported a very high reliance on laptop and smartphone combinations (78%), followed by laptop only (22%), as shown in Figure 4e. Additionally, the devices used by female students were

found to be laptop computer (56%) and smartphone (44%), as shown in Figure 5e, without any use of the desktop computer.

5. Discussion

The present survey was conducted among a group of participants who were being exposed to online learning for the very first time. It is important to note this point as this highlights the level of preparedness (or lack thereof) among the participants as they chose their devices to attend lectures, and participate in group projects and examinations. In this area, we observed some interesting trends among all schools. Firstly, the results revealed the popularity of the mobile phone and the unpopularity of the desktop computer. These trends remained consistent across a wide range of study groups: from engineering to music schools. The popularity of the mobile phone was attributed to its portability, built-in WiFI/4G hardware for internet access and relatively low cost. Conversely, the desktop could have been seen as bulky, not having a built-in battery, needing additional hardware to access the internet and being relatively expensive.

We like to point out similarities of the findings with other studies around the world. For example, in Nigeria, a relationship was uncovered between the digital divide in the student population and the socioeconomic status when accessing remote learning (Azubuike et al. 2021). In Bangladesh, the students highlighted low technological support, cost and speed of internet and personal financial issues from following remote learning during the pandemic (Ramij 2020). The preparedness could not be more starkly different as we see research related to using remote learning, even mobile-based learning technologies published as early as 2005: (Thornton and Houser 2005; Liu et al. 2012; Cook et al. 2008; Briz-Ponce et al. 2017).

Finding a sustainable solution to problems developing countries face when shifting to online learning is a clear challenge to educators and institutions at the same time.

6. Conclusions

The present study discussed extensively the challenges faced by students, especially those from developing countries, as they transitioned from traditional physical mode of education to online mode during the COVID-19 pandemic. In many ways, the barriers to the internet and other resource accessibility could be identified as similar for education systems in the developing countries, which were further strained by the demand for online education.

From another perspective, this paper asks and answers an important question "what are the go-to devices for students in higher education in a developing country for online learning during a crisis?" This was allowed as we were able to gather a dataset from students just as they were shifting to online education for the very first time. From the data we analyzed, we learned the importance of low cost of device, easy access to internet using inbuilt internet components and portability as key factors which could have shaped their decisions. The findings of the present study indicate possible opportunities for educators to take advantage in the future. For the rural parts of developing countries, mobile phones provide the most affordable option to connect to the internet and access online education, as was observed in a few cases in this study. In addition to engaging in formal online education with the lecturer, the devices also provide the opportunity for students to learn informally through their peers, which have been appreciated as a very effective way of learning. Furthermore, online tools for education could also increase the degree of interaction between students and lecturers, providing confidential channels to communicate one to one.

At the same time, there are new challenges to educators if the online learning behavioural patterns of students are considered for implementing new learning approaches. Considering the extensive use of mobile phones, it would be important to design lecture material/assessment which is mobilephone friendly. For example, the questions can be

broken down into smaller sections, allowing clear visibility through a smaller screen, compressed recorded videos and student responses which can be typed in.

However, even while using mobile phones as a measure to provide greater accessibility, the "digital divide" between urban and rural societies is plain to observe. While there are many benefits of online education, these benefits would not be uniformly appreciated if the services are limited to a few. At the same time, we need to outline the significant amount of user interface (UI) development work that needs to be undertaken to make such mobile-based solutions practical. Ideally, while allowing access to a wide-range of information, such a mobile-based application should also cater to communication between students and educators (Nuño-Maganda et al. 2020).

It is of paramount importance that there is further investment of expanding digital infrastructure providing higher bandwidth at a lower cost for educational purposes. After all, the internet is a great equaliser in that it provides access to many free educational resources: articles, books and various multimedia. It can be appreciated that online education is also a path to providing higher quality education at a lower cost, due to not being restricted to physical spaces and infrastructure. Hence, the pandemic showed many countries how their education systems could be more versatile and make education more accessible.

References

Almazova, Nadezhda, Elena Krylova, Anna Rubtsova, and Maria Odinokaya. 2020. Challenges and Opportunities for Russian Higher Education amid COVID-19: Teachers' Perspective. *Education Sciences* 10: 368. [CrossRef]

Araka, Eric, Elizaphan Maina, Rhoda Gitonga, Robert Oboko, and John Kihoro. 2021. University Students' Perception on the Usefulness of Learning Management System Features in Promoting Self-Regulated Learning in Online Learning. *International Journal of Education and Development Using Information and Communication Technology* 17: 45–64.

Azubuike, Obiageri Bridget, Oyindamola Adegboye, and Habeeb Quadri. 2021. Who Gets to Learn in a Pandemic? Exploring the Digital Divide in Remote Learning during the COVID-19 Pandemic in Nigeria. *International Journal of Educational Research Open* 2: 100022. [CrossRef]

Badge, Joanne L, Emma Dawson, Alan J. Cann, and Jon Scott. 2008. Assessing the Accessibility of Online Learning. *Innovations in Education and Teaching International* 45: 103–13. [CrossRef]

Basto-Aguirre, Nathalie, Paula Cerutti, and Sebastián Nieto-Parra. 2020. COVID-19 Can Widen Educational Gaps in Latin America: Some Lessons for Urgent Policy Action. Available online: http://vox.lacea.org/?q=blog/covid19_widen_educational_gaps (accessed on 23 July 2021).

Bax, Stephen. 2011. Normalisation Revisited: The Effective Use of Technology in Language Education. *International Journal of Computer-Assisted Language Learning and Teaching (IJCALLT)* 1: 1–15. [CrossRef]

Blundell, Richard, Monica Costa Dias, Robert Joyce, and Xiaowei Xu. 2020. COVID-19 and Inequalities. *Fiscal Studies* 41: 291–319. [CrossRef]

Briz-Ponce, Laura, Anabela Pereira, Lina Carvalho, Juan Antonio Juanes-Méndez, and Francisco José García-Peñalvo. 2017. Learning with Mobile Technologies–Students' Behavior. *Computers in Human Behavior* 72: 612–20. [CrossRef]

Cook, John, Norbert Pachler, and Claire Bradley. 2008. Bridging the Gap? Mobile Phones at the Interface between Informal and Formal Learning. *Journal of the Research Center for Educational Techology* 4: 3–18.

Daud, Alaa, Aaron Bagria, Kushal Shah, and James Puryer. 2017. Should Undergraduate Lectures Be Compulsory? The Views of Dental and Medical Students from a UK University. *Dentistry Journal* 5: 15. [CrossRef]

Dobransky, Kerry, and Eszter Hargittai. 2006. The Disability Divide in Internet Access and Use. *Information, Communication & Society* 9: 313–34.

Eurboonyanun, Chalerm, Jakrapan Wittayapairoch, Potchavit Aphinives, Emil Petrusa, Denise W. Gee, and Roy Phitayakorn. 2020. Adaptation to Open-Book Online Examination during the COVID-19 Pandemic. *Journal of Surgical Education* 78: 737–39. [CrossRef]

Evans, Jake. 2020. ANU to Use Facial Detection Software on Student Computers in Response to Coronavirus Remote Exams. *ABC. Net.* Available online: https://www.abc.net.au/news/2020-04-20/coronavirus-anu-to-use-ai-spying-software-on-student-computers/12164324 (accessed on 23 July 2021).

Favale, Thomas, Francesca Soro, Martino Trevisan, Idilio Drago, and Marco Mellia. 2020. Campus Traffic and E-Learning during COVID-19 Pandemic. *Computer Networks* 176: 107290. [CrossRef]

Gikas, Joanne, and Michael M. Grant. 2013. Mobile Computing Devices in Higher Education: Student Perspectives on Learning with Cellphones, Smartphones & Social Media. *The Internet and Higher Education* 19: 18–26.

Hanson, Vicki L. 2001. Web Access for Elderly Citizens. Paper presented at 2001 EC/NSF Workshop on Universal Accessibility of Ubiquitous Computing: Providing for the Elderly, Alcácer do Sal, Portugal, May 22–25; pp. 14–18.

Henderson, Michael, Neil Selwyn, and Rachel Aston. 2017. What Works and Why? Student Perceptions of 'useful' Digital Technology in University Teaching and Learning. *Studies in Higher Education* 42: 1567–79. [CrossRef]

Henry, Shawn Lawton, Shadi Abou-Zahra, and Judy Brewer. 2014. The Role of Accessibility in a Universal Web. In *Proceedings of the 11th Web for All Conference*. Seoul: Association for Computing Machinery.

Huang, Chaolin, Yeming Wang, Xingwang Li, Lili Ren, Jianping Zhao, Yi Hu, and Li Zhang. 2020. Clinical Features of Patients Infected with 2019 Novel Coronavirus in Wuhan, China. *The Lancet* 395: 497–506. [CrossRef]

Jæger, Mads Meier, and Ea Hoppe Blaabæk. 2020. Inequality in Learning Opportunities during COVID-19: Evidence from Library Takeout. *Research in Social Stratification and Mobility* 68: 100524. [CrossRef] [PubMed]

Josefsson, Pernilla, Alexander Baltatzis, Olle Bälter, Fredrik Enoksson, Björn Hedin, and Emma Riese. 2018. Drivers and Barriers for Promoting Technology-Enhanced Learning in Higher Education. Paper presented at 12th International Technology, Education and Development Conference (INTED), Valencia, Spain, March 5–7; pp. 4576–84.

Khan, Rehan Ahmed, and Masood Jawaid. 2020. Technology Enhanced Assessment (TEA) in COVID 19 Pandemic. *Pakistan Journal of Medical Sciences* 36: S108. [CrossRef] [PubMed]

Kim, Eunjoo, Hangsik Park, and JungUn Jang. 2019. Development of a Class Model for Improving Creative Collaboration Based on the Online Learning System (Moodle) in Korea. *Journal of Open Innovation: Technology, Market, and Complexity* 5: 67. [CrossRef]

Kim, Sang Hyun, Clif Mims, and Kerry P. Holmes. 2006. An Introduction to Current Trends and Benefits of Mobile Wireless Technology Use in Higher Education. *AACE Journal* 14: 77–100.

Komlenov, Zivana, Zoran Budimac, and Mirjana Ivanović. 2010. Introducing Adaptivity Features to a Regular Learning Management System to Support Creation of Advanced eLessons. *Informatics in Education* 9: 63–80. [CrossRef]

Layer, Geoff. 2017. *Disabled Students Sector Leadership Group (DSSLG) Inclusive Teaching and Learning in Higher Education as a Route to Excellence*. London: Department for Education.

Liu, Jinru, Shuang Hu, Jayaraman J. Thiagarajan, Xue Zhang, Suhas Ranganath, Mahesh K. Banavar, and Andreas Spanias. 2012. Interactive DSP Laboratories on Mobile Phones and Tablets. Paper presented at 2012 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP), Toronto, ON, Canada, April 14–17; pp. 2761–64.

Manca, Stefania, and Maria Ranieri. 2013. Is It a Tool Suitable for Learning? A Critical Review of the Literature on Facebook as a Technology-Enhanced Learning Environment. *Journal of Computer Assisted Learning* 29: 487–504. [CrossRef]

Mercader, Cristina, and Joaquín Gairín. 2020. University Teachers' Perception of Barriers to the Use of Digital Technologies: The Importance of the Academic Discipline. *International Journal of Educational Technology in Higher Education* 17: 1–14. [CrossRef]

Nafukho, Fredrick Muyia. 2007. The Place of E-Learning in Africa's Institutions of Higher Learning. *Higher Education Policy* 20: 19–43. [CrossRef]

Nuño-Maganda, Marco Aurelio, Cesar Torres-Huitzil, Yahir Hernández-Mier, Jorge De La Calleja, Carmen Carlota Martinez-Gil, José Hugo Barrón Zambrano, and Alan Díaz Manríquez. 2020. Smartphone-Based Remote Monitoring Tool for e-Learning. *IEEE Access* 8: 121409–23. [CrossRef]

Okiki, Olatokunbo Christopher. 2011. *Information Communication Technology Support for an Elearning Enviroment*. Lagos, Nigeria: University of Lagos.

Parsons, Anastassia. 2017. Accessibility and Use of VLEs by Students in Further Education. *Research in Post-Compulsory Education* 22: 271–88. [CrossRef]

Pearson, Efaine J., and Tony Koppi. 2002. Inclusion and Online Learning Opportunities: Designing for Accessibility. *Research in Learning Technology* 10: 17–28. [CrossRef]

Ramij, Afrin Sultana. 2020. Preparedness of Online Classes in Developing Countries amid COVID-19 Outbreak: A Perspective from Bangladesh. In *Afrin, Preparedness of Online Classes in Developing Countries amid COVID-19 Outbreak: A Perspective from Bangladesh*. June 29. Available online: https://dx.doi.org/10.2139/ssrn.3638718 (accessed on 23 July 2021).

Remtulla, Ridhaa. 2020. The Present and Future Applications of Technology in Adapting Medical Education amidst the COVID-19 Pandemic. *JMIR Medical Education* 6: e20190. [CrossRef]

Robinson Danielle, Sani Aisha, and Aminu Zainab Rahima. 2020. New Skills for Youth to Succeed in the Post-COVID World. *Worldbank.Org*. Available online: https://blogs.worldbank.org/digital-development/new-skills-youth-succeed-post-COVID-world (accessed on 23 July 2021).

Sam, Amir H., Michael D. Reid, and Anjali Amin. 2020. High-Stakes Remote-Access Open-Book Examinations. *Medical Education* 54: 767–68. [CrossRef] [PubMed]

Samadbeik, Mahnaz, Donya Yaaghobi, Peivand Bastani, Shahabeddin Abhari, Rita Rezaee, and Ali Garavand. 2018. The Applications of Virtual Reality Technology in Medical Groups Teaching. *Journal of Advances in Medical Education & Professionalism* 6: 123.

Schur, Lisa, Douglas Kruse, and Peter Blanck. 2005. Corporate Culture and the Employment of Persons with Disabilities. *Behavioral Sciences & the Law* 23: 3–20.

Sife, Alfred, Edda Lwoga, and Camilius Sanga. 2007. New Technologies for Teaching and Learning: Challenges for Higher Learning Institutions in Developing Countries. *International Journal of Education and Development Using ICT* 3: 57–67.

Soliman, Maged, Apostolos Pesyridis, Damon Dalaymani-Zad, Mohammed Gronfula, and Miltiadis Kourmpetis. 2011. The Application of Virtual Reality in Engineering Education. *Applied Sciences* 11: 2879. [CrossRef]

Thornton, Patricia, and Chris Houser. 2005. Using Mobile Phones in English Education in Japan. *Journal of Computer Assisted Learning* 21: 217–28. [CrossRef]

Tsironis, Alexandros, Christos Katsanos, and Michail Xenos. 2016. Comparative usability evaluation of three popular MOOC platforms. Paper presented at 2016 IEEE Global Engineering Education Conference (EDUCON), Abu Dhabi, April 11–13.

Valdez, M. Travassos, C. Machado Ferreira, Maria João M. Martins, and F. P. Maciel Barbosa. 2014. Virtual labs in electrical engineering education—The VEMA environment. Paper presented at the 2014 Information Technology Based Higher Education and Training (ITHET), York, UK, September 11–13.

Valverde-Berrocoso, Jesús, María del Carmen Garrido-Arroyo, Carmen Burgos-Videla, and María Belén Morales-Cevallos. 2020. Trends in Educational Research about e-Learning: A Systematic Literature Review (2009–2018). *Sustainability* 12: 5153. [CrossRef]

Vergara, Diego, Jamil Extremera, Manuel Pablo Rubio, and Lilian P. Dávila. 2020. The proliferation of virtual laboratories in educational fields. *Advances in Distributed Computing and Artificial Intelligence Journal* 9: 85–97. [CrossRef]

Vergara, Diego, Manuel Pablo Rubio, and Miguel Lorenzo. 2017. New Approach for the Teaching of Concrete Compression Tests in Large Groups of Engineering Students. *Journal of Professional Issues in Engineering Education and Practice* 143: 05016009. [CrossRef]

Viegas, Clara, Arcelina Marques, Gustavo R. Alves, and Francisco García-Peñalvo. 2019. Engineering Education and Technological/Professional Learning. *Education Science* 9: 277. [CrossRef]

Zhu, Chang. 2015. Organisational Culture and Technology-Enhanced Innovation in Higher Education. *Technology, Pedagogy and Education* 24: 65–79. [CrossRef]