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A Comprehensive Overview of Education during Three COVID-19 Pandemic Periods: Impact on Engineering Students in Sri Lanka

Gayanthi A. Ilangarathna [1,*], Yasiru Ranasinghe [1], Harshana Weligampola [1], Erandi Attygalla [1], Janaka Ekanayake [1], Sakunthala Yatigammana [2], Mallika Pinnawala [2], Roshan Godaliyadda [1], Vijitha Herath [1], Parakrama Ekanayake [1], Ganga Thilakaratne [3] and Samath Dharmarathne [4]

1 Faculty of Engineering, University of Peradeniya, Peradeniya 20400, Sri Lanka; e14273@eng.pdn.ac.lk (Y.R.); harshana.w@eng.pdn.ac.lk (H.W.); erandiattygalla@gmail.com (E.A.); ekanayakej@eng.pdn.ac.lk (J.E.); roshangodaliyadda777@gmail.com (R.G.); vijitha@eng.pdn.ac.lk (V.H.); mpb.ekanayake@gmail.com (P.E.)
2 Faculty of Arts, University of Peradeniya, Peradeniya 20400, Sri Lanka; sakuyatigammana@gmail.com (S.Y.); mallikap@pdn.ac.lk (M.P.)
3 Institute of Policy Studies, Colombo 00700, Sri Lanka; ganga@ips.lk
4 Faculty of Medicine, University of Peradeniya, Peradeniya 20400, Sri Lanka; samath.dharmaratne@med.pdn.ac.lk
* Correspondence: emgaillangarathna@gmail.com

Abstract: The COVID-19 pandemic has impacted the education system in Sri Lanka, similar to many countries in the world. As a result, the mode of education shifted from conventional face-to-face classes to online mode. The main objective of this study is to provide a comprehensive overview of the changes to the educational system due to the COVID-19 pandemic among engineering undergraduates of Sri Lanka over three identified pandemic periods. Quantitative descriptive analysis was used together with chi-square statistics to answer the research questions using the data collected through a google survey from engineering undergraduates in Sri Lanka. According to the results, students' attendance in online classes has improved over time compared to the initial pandemic period. Nearly 50% of students' family income has been impacted, either stopped or reduced due to the pandemic. Most students have issues regarding computing devices, internet connectivity, and the home environment. According to the chi-square statistics results, few of these issues had a statistically significant relationship between the family income; lower the income, higher the negative impact on students. More than half of the students felt isolated when studying at home during the pandemic. Still, more than 50% of students agreed that lecturers were well prepared to guide and deliver lessons remotely. The overall recommendations of the study are implementing workshops, training on new technologies, awareness programs for educational stakeholders, providing incentives to purchase digital devices, and improving internet connectivity to improve the new standard education system of Sri Lanka.

Keywords: COVID-19 impact; online learning; face-to-face learning; income

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1. Introduction

The World Health Organization (WHO) [1] declared COVID-19 a global pandemic on 11 March 2020. This disease had begun in Wuhan, China, and has spread to more than 220 countries and territories. As of 29 December 2021, more than 281 million cases and more than 5.4 million deaths have been reported in the world [2]. To keep the pandemic at bay, the majority of the countries have restricted gatherings of people, mobility, and the most severe measures like curfews and complete shut-downs [3]. The main objective was to decrease and delay an epidemic's peak by "flattening the curve" [4]. The lockdown has had a toll on the livelihood of people working in various sectors [5]. However, there are

many claims about these containment strategies globally due to their severe impact on many aspects of human life.

Education is fundamental to development, growth, and interventional activities to combat the pandemic-induced crisis. Thus, the impact on the educational sector has been extensive and complex during the past one and half years. In conformity with the global acceptance of social distancing policy, as announced by WHO to curb the spread of COVID-19, schools have been forced to close their doors, which has caused inevitable disruption to traditional teaching and learning methods [6]. As of June 2021, 42.5% of the schools had been closed in the world, and around 38% of countries kept schools either fully or partially closed. Accordingly, 63% of countries have been using online education as a remote delivery method since June 2020. Overall, the most significant impact of school closures on students can be seen in Central and South Asia due to the sheer number of students in these sub-regions (UNESCO, 2021).

Sri Lanka is a critically affected south Asian country by COVID-19 pandemic; as of 2 January 2022, Sri Lanka has reported 587,935 cases and 15,019 deaths [7]. Throughout more than a year and a half, Sri Lanka experienced different waves of the Corona pandemic, namely, the first wave (period from 27 March 2020–3 October 2020), the second wave (from 4 October 2020–14 April 2021), and third wave (15 April to date) [8]. As a result, severe lockdowns and curfews were imposed to control the spread of the disease. Due to the restrictions that prevailed, the closure of all schools and tertiary education institutions in Sri Lanka was announced on 12 March 2020 (Government Press Release). This closure created many challenges to the education system; admissions, ceremonies, assessments, and examinations were temporarily postponed. As a result, the majority of the tertiary education institutes like state universities were forced to adopt complete remote learning systems in many disciplines of studies. According to UNESCO [9], the closure of schools resulted in 50% of school students engaging in education via the internet, which on average varies from 8% in smaller schools with poor facilities to 59% in larger schools where better facilities are available. However, this massive transition in the educational system opens a wide array of research gaps in the Sri Lankan education system.

1.1. Online Learning during the COVID-19 Pandemic

The digital transformation of higher education runs back to some years, and it is not novel in the world [10,11]. Distance education which runs back to the 1830s [12], turns to internet-based online education with the technological interventions during the 1990s [13]. However, among the features of the digital transformation of higher education, online education is one of them [6].

Conventional online education is a well-planned and managed system of education under expertise, knowledge and experiences [14], and it is a technique of transferring and acquiring knowledge using technological applications over the internet [15]. According to [16], online learning is the use of the internet and other vital technologies to develop materials for educational purposes, instructional delivery, and management of the program. Thus, online education is as effective as face-to-face learning when properly designed [17,18]. Further, comprehensive awareness of the limits and benefits of online education by the organization and the instructors will make online education an efficient and effective platform [19]. This novel social process of online learning transformation is not a matured and well-trained method of teaching and learning process but similar to a ban-aid for a temporary injury due to the pandemic situation [20]. This is known as Emergency Remote Teaching (ERT), which is characterized by a "temporary shift of instructional delivery to an alternative delivery mode due to crisis circumstances" wherein its main purpose is "not to re-create a robust educational ecosystem but rather to provide temporary access to instruction and instructional supports" [21]. This is the first time where ERT has been implemented worldwide. This change made most of the students and teachers shift to online education abruptly, causing some to feel stressed and anxious while some others took this as a positive opportunity [22].

COVID-19 made Sri Lanka to exclusively taught all courses using online platforms [23] for the first time in history. This approach is a new facet of the education system for Sri Lanka, as universities were practicing conventional face-to-face classes before the pandemic. However, before the pandemic, teachers used various e-learning tools in their teaching practices to assist the conventional delivery of courses. The government took a number of measures to reduce the burden and cost of online education, such as providing Zoom access free of data charges via Lanka Education and Research Network (LEARN) for the universities [24]. Furthermore, many universities used their Moodle-based learning management systems to post-academic materials for students. This novel experience created many challenges and opportunities for Sri Lankan higher study pedagogy.

1.2. Feeling towards Online Education and Problems Face When Studying at Home

Karalis and Raikou [25] showed that 77.7% of students in the Department of Educational Sciences in Greece had a negative feeling about online education upon the closure of the University, but it was decreased significantly (from 77.7 to 46.6%) while engaged in online education. Further, their positive emotions were increased correspondingly (from 8.7% to 37.9%) when engaged in online education. According to [26], most undergraduate students believe that their technical skills will improve through online education compared to usual in-person classes, even though online education is less effective for the communication between teachers and students. The study by Bhaumik & Priyadarshini [27] stated that most of the students believe that online education and face-to-face education are equally good. The findings of [28] show that 74% of respondents liked online education mainly due to the flexibility of time and location, which motivates people for blended education.

According to the literature, the preference and feelings towards online education were diverse. A study conducted with Indian undergraduates found out that the disruption of the usual education system, uncertainties of the future, and the fear of the virus have created emotional instability among students [5]. The lack of motivation, procrastination, and difficulty concentrating was commonly reported, as well as fear and anxiety, confusion, stress, and worry about academic failure [25]. Further, they have shown that the majority (70.9%) have mentioned the lack of personal contact between teacher and students and among students, the difficulty of concentrating and participating in the class (21.4%), as well as the lack of physical presence on campus (8.7%) as some of the disadvantages of online education over the traditional face-to-face classes. According to Kalman et al. [29], many undergraduate students who study chemistry viewed online learning as a challenge to overcome. A study conducted with school students in the East Midlands region of the United Kingdom found that 78.8% of students had felt lonely when studying through online platforms during the pandemic lockdown period, concluding that overall increase in the extent of loneliness due to online education [30].

Moreover, socio-economic factors of students have significantly impacted the success of online education. The prevailing financial instabilities, lack of knowledge, and resources to access online platforms for education are high in rural areas of India. Among them, most rural students do not have access to mobile phones and laptops [5]. Further, according to Bhaumik & Priyadarshini [27], about 30–40% of students have problems accessing devices and a good internet connection which negatively affects effective online education. According to Kalman et al. [29], students felt that it is difficult to work and improve their study habits from home.

This study focuses on the impact of COVID-19 on education in Sri Lanka due to the long-term and multi-pronged impact on education from the pandemic. Given the situation, although few studies have been done on the impact of COVID-19 on education in the country, the impact on tertiary education, especially on engineering and technology-related education, was identified as a gap of research. Further, engineering is a discipline where teaching and learning methods include lecture room teaching theoretical concepts and hands-on laboratory designs and experiments in normal circumstances. Therefore, due to the diversity of delivery and their high exposure to modern technology, this study was

focused on engineering undergraduates in Sri Lanka. The specific research questions of this study are: (a) what are the patterns of online class involvement and the students' preference towards modes of education in different pandemic periods, (b) what are the issues faced when studying through online platforms and related to the home environment, and (c) what are the feelings of students when studying remotely.

2. Materials and Methods

The methodological approach of this study is quantitative, which is appropriate to quantify behaviors, opinions, attitudes, and other variables to generalize from a larger population. Further, quantitative research tries to quantify a problem and understand its prevalence by looking at results that can be projected to a larger population and end with conclusions/recommendations. This would help to see the big picture.

In this study, a survey method in a questionnaire was used. Supporting the selection of this, [31] suggests that a questionnaire is a usual and commonly used method to collect data from many respondents. It enables one to get a broader picture and an overview. Explaining the advantages of using a survey for research, [32] stated that a questionnaire allows collecting data in a standardized way, facilitating internal consistency and coherence. Prevailing social distancing measures and travel restrictions warranted an online survey for the data collection. The questionnaire was prepared as a 'Google form' by Alphabet Inc., Mountain View, California, United States, and distributed online via email and WhatsApp by Meta Platforms Inc., Menlo Park, California, United States.

Data were gathered for three specific pandemic periods: First wave, Post first wave, and Second wave. These periods were identified according to the containment strategies imposed by the government. During the first wave period (27 March 2020–28 June 2020), a complete shutdown of the country has prevailed, and all the educational institutions were closed completely. In the post first wave period (28 June 2020–4 October 2020), the country was back to normal and lifted the lockdown; universities were opened for examinations and practical sessions, as usual, following the health guidelines. In the second wave period (from 4 October 2020–14 April 2021), strict travel restriction was imposed. During this period, all the universities were closed, and a complete shift to online education occurred.

A well-structured questionnaire with clearly defined periods was used. There were 15 questions in the questionnaire. Every related question was repeated for all three periods. All the questions were closed-ended, with answers to be selected. Yet most of the questions had an 'other' section to facilitate answering any other comments or answers rather than the given choices. An extract of the questionnaire is included in Appendix A.

Responses were collected from engineering undergraduates of 6 state universities: the University of Peradeniya, the University of Jaffna, the Wayamba University of Sri Lanka, South Eastern University, the University of Sri Jayawardenepura, and the University of Kelaniya. Before distributing the survey, official notice was sent to the Deans of each faculty. Under official permission, the survey was distributed among the students by the lecturers from the specific universities. The study instrument was approved as ethically accepted by the Ethical review committee, Faculty of Arts, the University of Peradeniya, acceptable to all the other sister universities. The convenience sampling method was practiced to select the sample.

As can be seen from Appendix A, the survey collected data on different dimensions related to online education; about the class participation pattern, preference, and idea towards the mode of classes during different pandemic periods, about the devices used for online education, problems when accessing to devices, problems when accessing the internet services, and problems when learning from home and finally about the feelings when studying at home through online platforms. Pilot tests were conducted via telephone interviews due to the country's prevailing travel restriction policies. The validity of the questionnaire was checked according to the data collected through the pilot test and the comments from experts. The authors validated the responses considering known factors about these three periods and screened out the data set before using the data for analysis. All

the participants were between 20–25 years old, and they were provided with a description of the purpose of the survey mentioning that their participation is voluntary and could terminate the survey at any time or refuse to answer specific questions.

Quantitative descriptive analysis was utilized together with chi-square statistics to answer the research questions. The Chi-square test is useful to check the association between non-parametric variables. Therefore, the following hypotheses were tested using chi-square analysis and descriptive analysis to answer the research questions.

1. There is no statistically significant relationship between household income level and the impact on household income due to COVID-19.
2. There is no statistically significant relationship between income level and access to devices.
3. There is no statistically significant relationship between income level and access to an internet connection.

All the descriptive analyses and cross-tabulations were conducted using Statistical Package of Social Science (SPSS) software by SPSS Inc., Chicago, Illinois, United States, version 26.

3. Results and Discussion

This section includes the results produced by the analysis and the related discussion. Further, Section 3.1 discusses the income categories and impact on family income due to COVID-19. Section 3.2 discusses the online class participation pattern, preference, and impression towards the mode of classes. Section 3.3 discusses the issues faced when accessing online education, such as accessing devices, accessing the internet, and issues related to the home environment and the impact of family income for the relevant issues. Section 3.4 discusses the feelings when learning at home through online platforms.

For this study, students from all around the country have participated, and Figure 1 displays the geographical distribution of the respondents. Out of 389 responses, 367 students have completed the whole survey, which is an adequate sample for descriptive analysis [33,34]. Of 367 undergraduates, the highest percentage of participants was 12.8% from the Kandy district. The Gampaha district, with 11.4%, follows this. The districts under the northern province: Kilinochchi, Mannar, and Vavuniya, have the least response rate, followed by Eastern province; Trincomalee, Batticaloa, Ampara, and Monaragala district in Uva province.

3.1. Income Categories and Impact on Family Income Due to COVID-19

According to [33], the mean monthly income of a family with four members in Sri Lanka is LKR 62,237 (1 USD = 202.18 LKR). Table 1 shows the distribution of the family income within the identified income categories; <LKR 25,000, LKR 25,000–50,000, LKR 50,000–80,000 and >LKR 80,000. The monthly family income of 28% of students is greater than LKR 80,000, while only 14% of students' family income recorded less than LKR 25,000, followed by 27% and 25% of students for LKR 25,000–50,000 and LKR 50,000–80,000 categories, respectively.

Table 1 shows the impact on the income according to the income category. The chi-square value (0.00) for the cross-tabulation analysis between the income category and the impact on a student's family income is less than 0.05. Therefore, the null hypothesis was rejected, and the alternative hypothesis, a statistically significant relationship between income and the impact of COVID-19, can be accepted. Accordingly, 50% of students' family income had been changed, either increased, reduced, or stopped due to the pandemic; 42.4% had experienced a reduction, 6.3% had experienced a complete loss of income, and 1.2% had experienced an increase in income. 45% of family income had not changed due to the pandemic during the identified periods. Further, income reduction was highest in low-income groups within the income categories. Accordingly, the percentages of families whose income reduced during the pandemic were 65.4%, 49.5%, 38.0% and 27.9% in <LKR 25,000, LKR 25,000–LKR 50,000, LKR 50,000–LKR 80,000 and >LKR 80,000 categories respectively. It is observed that the higher the income lower the impact. The same trend was seen for the families whose income stopped. Thus, the percentages of families whose

income had been stopped; 13.5% in <LKR 25,000, 7.1% in LKR 25,000–LKR 50,000, 4.3% in LKR 50,000–LKR 80,000 and 3.8% in >LKR 80,000 income categories. These results imply that higher-income categories are less prone to impact a student's family income due to the pandemic.

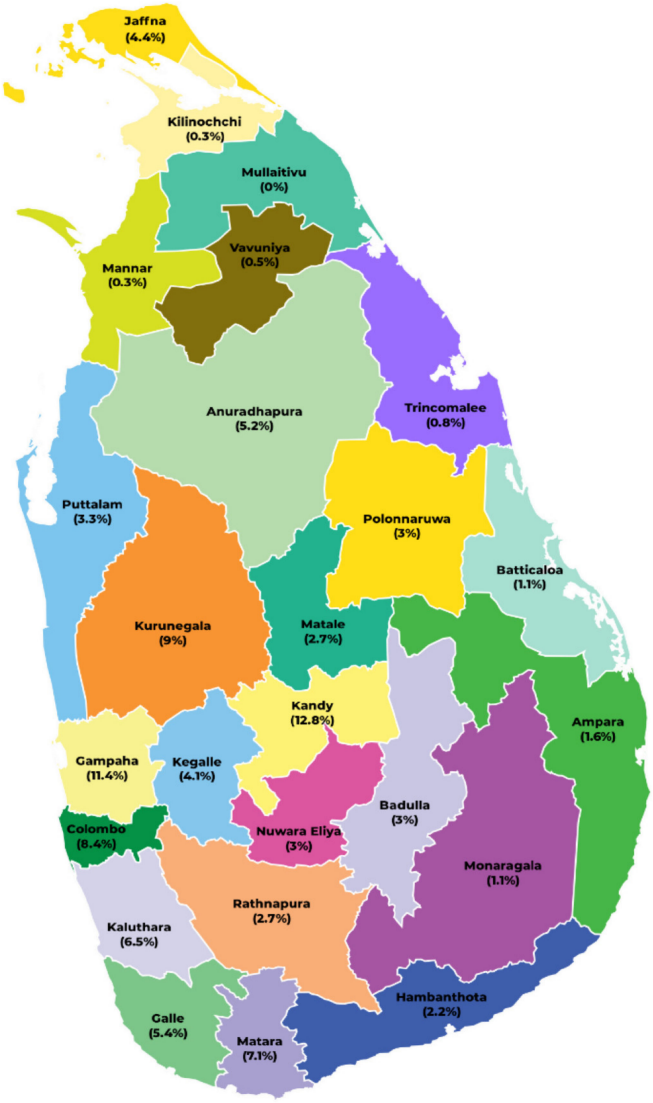

Figure 1. Distribution of respondents according to the residential districts in Sri Lanka.

Table 1. Family income categories of the students and the impact on income distribution due to COVID-19 pandemic.

	Income Category (LKR)				
	<25,000	**25,000–50,000**	**50,000–80,000**	**>80,000**	**Total**
Frequency of students under different income categories (No.)	53	99	93	104	349
Percentage of students under different income categories (%)	14.4	27	25.3	28.3	95.1

Table 1. *Cont.*

	Income Category (LKR)				
	<25,000	**25,000–50,000**	**50,000–80,000**	**>80,000**	**Total**
	Impact on the family income				
Income stopped (%)	31.8 (13.5)	31.8 (7.1)	18.2 (4.3)	18.2 (3.8)	6.3
Income reduced (%)	23.1 (65.4)	33.3 (49.5)	23.8 (38)	19.7 (27.9)	42.4
No change (%)	5.1 (15.4)	22.4 (35.4)	31.4 (53.3)	41 (61.5)	45
Income increased (%)	25 (1.9)	0 (0)	0 (0)	75 (2.9)	1.2
No idea (%)	11.1 (3.8)	44.4 (8.1)	22.2 (4.3)	22.2 (3.8)	5.2

Pearson Chi square Value = 0.000. The numbers in the parentheses are the percentages within the income category.

3.2. Online Class Participation Pattern, Preference, and Idea towards Modes of Classes

3.2.1. Change in Online Class Participation Pattern

Figure 2 shows the pattern of change in attendance to online classes during the pandemic periods. It seems that students' engagement in online classes had been improved over time. Accordingly, during the first wave period, 25.3% participated in online classes for all the classes, while 23.2% of students never participated in online classes. The percentage of students who have never participated in an online class was reduced over time to 17.7% in the post-first wave period and 7.6% in the second wave period from 23.2% in the first wave period.

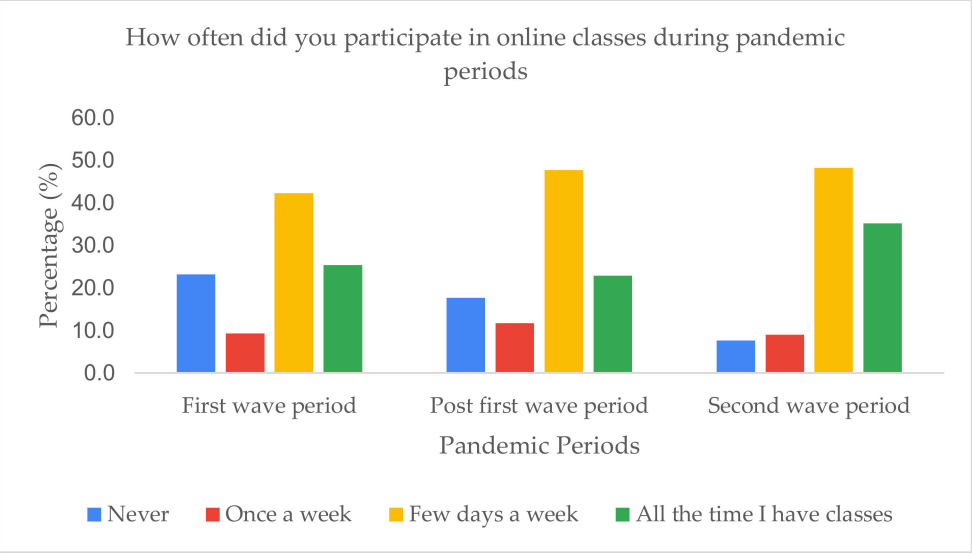

Figure 2. Frequency of online class attendance during the pandemic period.

According to Hemantha [30], during the pre-pandemic, among the school students in the United Kingdom, roughly 3% were using online resources; whereas, during the pandemic lockdown, it increased significantly to 18.2%, suggestive of a pivot towards online learning. According to the results of this study, only 25.3% participated in online classes always when they had classes, during the first wave period. Nevertheless, 35.1% of the increased participation rate in the second wave period reveals that students adapt to online education. Besides the challenges and the novelty, engineering students tried to adapt to the new normal situation in the education system. The advantages like time flexibility, less distraction from class members, improvement of technological skills, and knowledge have motivated more students to engage in online education.

3.2.2. Preference and Idea towards Modes of Classes

Further, Table 2 shows the impression towards the level of education and whether they had learned something extra apart from the academic-related work during the consecutive pandemic periods. Accordingly, 57.4% of students mentioned that within a week during the first wave period, they had learned more petite than the typical week in the pre-pandemic period. However, during the consecutive pandemic periods, the proportion of students who had learned less was reduced prominently. Furthermore, compared to the first wave period, 3% more students reported learning more than the pre-pandemic period during the second wave period. The results depict that the students were improving their skills and knowledge of online platforms and accessing more knowledge pools than typical face-to-face classes.

Table 2. Level of learning during three pandemic periods.

	In the First Wave Period	Post First Wave Period	Second Wave Period
How do you feel the level of education compared to a week in the pre-pandemic period?			
I learned less	57.2% (210)	44.1% (162)	43.65% (160)
I learned about as much	32.4% (119)	46.9% (172)	43.1% (158)
I learned more	10.4% (38)	9% (33)	13.4% (49)
Did you learn something extra apart from academic work?			
Yes	65.9% (242)	53.7% (197)	64% (235)
No	34.1% (125)	34.1% (125)	36% (132)

The numbers in the parentheses are the absolute numbers for the percentages provided.

Further, during the first wave period, 65.9% of students had learned something extracurricular (e.g., cooking, music, playing instruments, singing, and dancing) while it had been reduced to 53.7% in the post first wave period and again increased to 64% in second wave period. During the first wave period, the whole country had gone to a complete lockdown; it was a time when the university system had not adopted online education. Therefore, compared to the other two periods, students had the freedom to do extracurricular activities or academic work as they preferred. However, more students tend to learn something extracurricular than in the pre-pandemic period.

However, students' preference towards typical face-to-face classes remained high compared to the novel remote learning system. According to Table 3, most of the students (46%) preferred a mix of online and face-to-face classes and only 10.1% of students preferred only online education.

Table 3. The preference on modes of class.

	N = 367
Mode of Class	**Percentage (%)**
In-person Classes	43.9
Online Classes	10.1
A mix of both in-person and online	46.0

These findings are supported by the study of Hashemi [34], where 194 students liked online education while 607 students preferred face-to-face classes. Further, according to Yates et al. [35], only 10% preferred learning at home compared to face-to-face classes in classrooms among high school students

3.3. Access to Online Education and Related Issues

This subsection discusses the access to online education and issues faced when engaging in online education. This includes issues related to accessing digital devices, internet connection, and the home environment.

3.3.1. Devices Used for Online Education and Issues When Accessing Devices

Figure 3 illustrates the types of devices used by students during the pandemic for their online educational purposes. The findings show that most students use their own mobile phones/smartphones for online learning (45.2%). This is followed by own laptop (41.9%) and a device used by other family members (6.5%). Accordingly, about 87% of students have their own devices which can be used for their education.

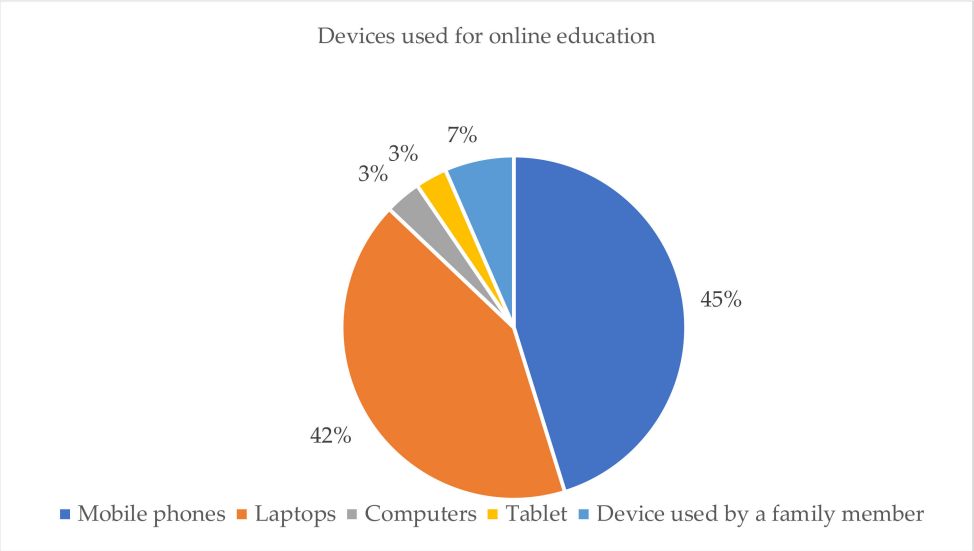

Figure 3. Devices used for online learning.

During the pandemic, students' academic performance might be affected by racial, economic, and resource differences [36]. Lack of digital devices during the lockdown of COVID-19 limited the continuation of online education. For online learning to be a reality, having a device and proper internet connection are crucial factors; without that, the education system may experience the frequently quoted 'digital divide' [27]. From a study conducted in the South Eastern University of Sri Lanka [24], it was found out that most of the students in the university have faced challenges with access to devices, and among them, most of the students relied on university resources during the pre-pandemic period [24]. Table 4 shows the frequency and the percentage of students facing issues when accessing a digital device. Accordingly, more students have device malfunctioning/power outage problems (39.8%), while 18.3% face problems in sharing the device. However, 25.6% of students did not have any issue accessing to a device. Further, these results imply that most of the students had access to a device, and still, they had considerable issues with device malfunctioning/power outages.

While online education would have been the readily available solution, it has widened inequalities in access to education and fueled social unrest as some population groups, specifically those residing in rural areas, do not have access to the facilities and infrastructure necessary for online learning. However, there are still issues when accessing online learning devices among engineering undergraduates in Sri Lanka.

The chi-square value is 0.016, which is lesser than 0.05, which implies rejecting the null hypothesis and accepting the alternative hypothesis; there is a statistically significant relationship between income level and access to devices. Figure 4 shows two graphs with

the cross-tabulation percentages of students who had and had no issues when accessing devices and among the income categories.

Table 4. Issues when accessing to a device.

	Responses	
	Frequency	**Percentage (%)**
No device	16	3.7
Had to share among family members	80	18.3
Device malfunctioning/power outages	174	39.8
No issues	112	25.6
Other	55	12.6
Total	437	100.0

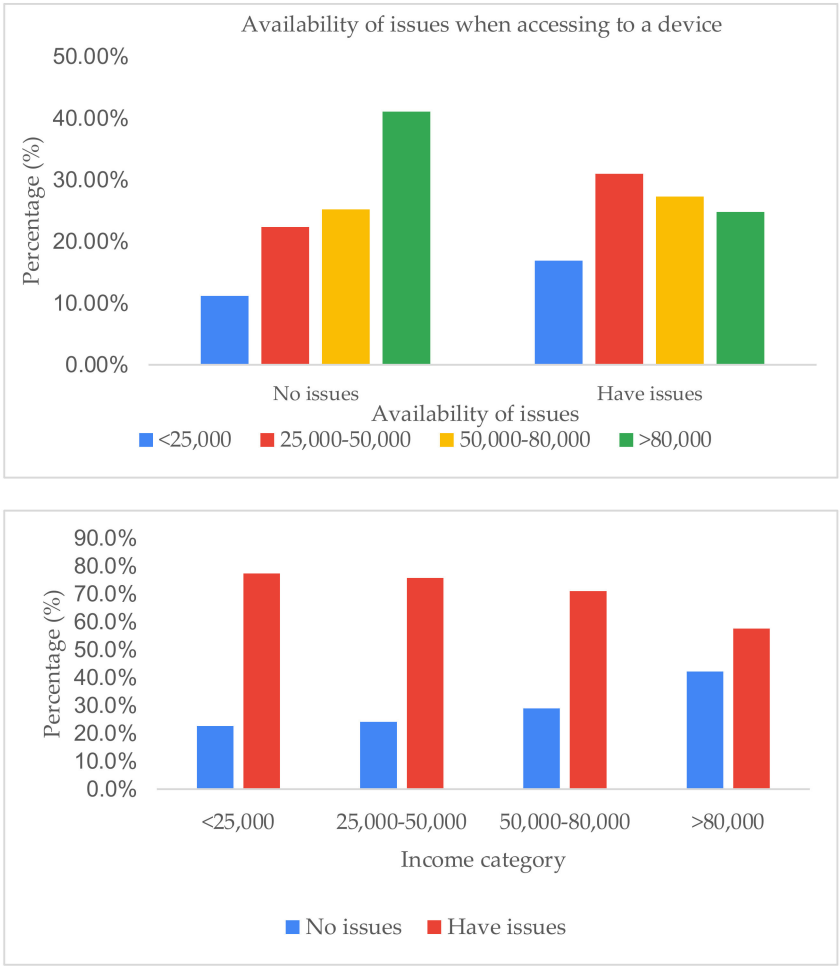

Figure 4. Percentage of students who had issues regarding accessing to devices under each income category (Pearson Chi-square Value = 0.016).

Among the students who have not had any issues when accessing a device, only 11.2% are under <LKR 25,000 monthly income category while it is 41.1% for the income category >LKR 80,000. Within the <LKR 25,000 group, 77.4% had issues accessing a device, while only 57.7% had issues for >LKR 80,000 group. The literature argued that students with good self-discipline, knowledge, emotional intelligence and fluency in technology would perform well in remote education [37,38]. Even for a student with the aforementioned qualities, one may be unsuccessful in using remote learning due to lack of resources and poor socio-economic factors such as financial instability and family support. This implies

that the family's financial stability will impact access to digital devices that are important for online education.

3.3.2. Issues When Accessing the Internet

The access to online education was restricted by device availability and lack of technical knowledge, proper learning environment at home, and accessibility to the internet. The internet is a vast interconnected network of information and communication and helps students find relevant and useful study materials. Students with bad internet connections are denied of accessing online learning [6]. In Sri Lanka, students in many rural areas face several difficulties getting a better internet connection.

Table 5 shows the frequency and percentage of students who had issues accessing internet connection. Accordingly, most of the students had multiple issues, while only 1.9% did not have any issues accessing the internet. Among the students, 36.7% had connectivity issues which was the biggest issue related to the internet connections. The second-largest issue is package limitation difficulty, where 27.7% of students had indicated. Most internet packages are limited and restricted for specific time durations as daytime and nighttime data. Therefore, this made students experience difficulties when accessing internet services.

Further, 26.6% had mentioned they faced internet traffic issues during the classes. This may be due to a higher number of online classes at the same time in the country. However, 5.8% of students were unable to purchase internet service.

Table 5. Issues with accessing to the internet connection.

	Responses	
	Frequency	**Percentage (%)**
Connectivity issues	305	36.7%
Unable to purchase the service	48	5.8%
Package limitations	230	27.7%
Internet traffic issues	221	26.6%
No issues	16	1.9%
Other	10	1.2%
Total	830	100%

According to [24], the financial difficulties among students created a lack of access to the internet in Sri Lanka. Figure 5 shows percentage distribution by the cross-tabulation results with the family income level and availability of issues when accessing an internet connection. The results show that the Pearson chi-square value is 0.018, which is less than 0.05, implying accepting the alternative hypothesis, there is a statistically significant relationship between access to an internet connection at a 5% level. The quantitative data depicts that, among the students who were unable to purchase an internet package, more than 50% of their monthly income is below LKR 50,000. Further, more than 50% of their family income has been affected negatively by the pandemic; either their income reduced or stopped due to the pandemic. This implies that lower economic levels are severely impacted by the pandemic and make it difficult for students to engage in online education compared to face-to-face classes.

This shows that most of the students had faced problems when accessing internet connections, and among them, most of their family income has been impacted significantly, making disparities among students when accessing online education. Supporting this finding, Fishbane and Tomer [39] findings also show that due to the pandemic, poverty increases in the community, and the rate of internet accessibilities declined rapidly. By implications, students with no or low socio-economic power to afford internet connection are most vulnerable to fall behind or encounter additional challenges to meet up with others in online learning.

In the authors' opinion, online education will be successful with proper devices and internet connections. It enhances engagement in online education. However, students'

digital literacy, motivation towards studies, and other socio-economic factors are also important for the success of online education.

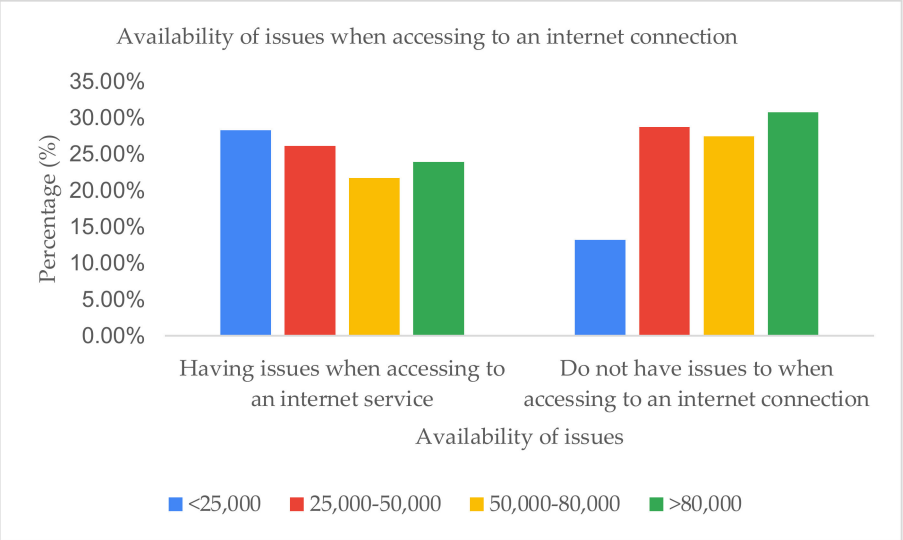

Figure 5. Percentage of students with the inability to purchase an internet connection and who had no issues when purchasing an internet connection under each income category.

3.3.3. Issues Related to the Home Environment

Shifting from face-to-face classroom education to online education at home created different challenges and opportunities [35] for students. The ability to choose what, how, and when to study beyond synchronous scheduled activities; and anytime access to resources are more flexible when studying at home. Table 6 depicts the percentages and frequencies of students who had issues related to the home environment.

Table 6. Issues when studying at home.

Problems When Studying at Home	Responses	
	Frequency	Percentage (%)
Problems with finding a quiet place to study	145	20.8
Problems with finding time to study because I had household responsibilities	99	14.2
Problems with finding someone who could help me with my studies	175	25.1
Problems with motivating myself to do studies	200	28.7
No Issues/ Problems	36	5.2
Other	41	5.9
Total	696	100

Accordingly, 28.7% of students had the problem of motivating themselves for studies. Further, 25.1% of the students have the problem of finding someone who could help with their studies at home. Contrary to this finding, according to Jamalpur et al. [40], 94% agreed that they had received the necessary support from their family members during the period of learning at home. Further, 20.8% had a problem finding a quiet place to study, which is also supported by [27]. This may be due to the unavailability of internet access at quiet places, and maybe family members are not aware and understandable about the novelty in the educational system.

Further, 14.2% of students have family responsibilities like looking after siblings, helping with housework, and other family engagements during their study time, which has created a problem for their education. Results show that most students have either

one or more problems when studying at home, and only 5.2% have mentioned that they do not have any problems. These results interpret that, though time is flexible when they are studying at home, still they are facing external problems compared to the periods when they are studying at universities in person. This creates disparities between students and their performance in education. In the long term, it affects their physical and mental well-being. However, problems like less motivation, lack of a quiet place, less support among students have been reported in many parts of the world [35].

3.4. Feelings about Learning at Home through Online Platforms

Both positive and negative feelings are reported in the literature when studying remotely [40,41]. Loneliness, anxiety, and lack of motivation are predominant in many findings when studying remotely. Figure 6 shows the proportion of students who agree, disagree or are neutral for the statements about their feelings when learning at home.

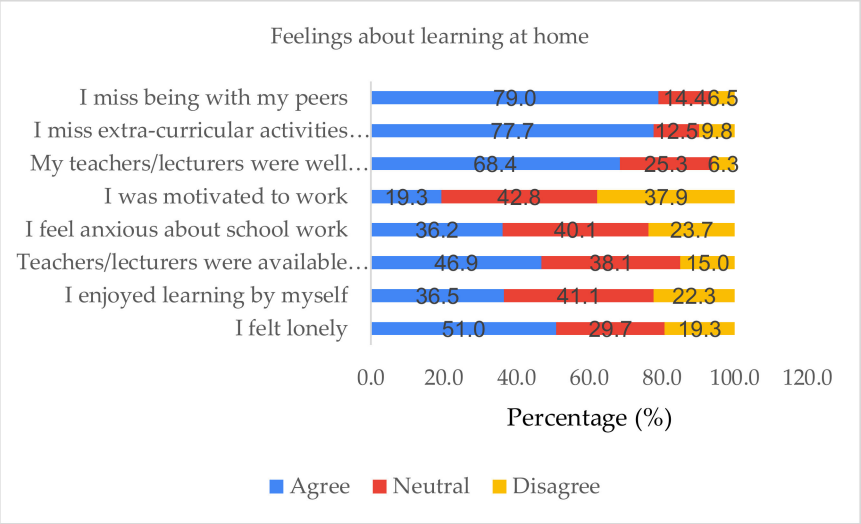

Figure 6. Students' self-evaluation regarding the feeling about learning at home.

Accordingly, 77.7% of respondents stated that they had missed extra-curricular activities due to the lockdown and studying at home. Only 9.8% of students disagreed with the statement and believe that they have not missed extra-curricular activities besides the lockdown or studying remotely. This will create long-term issues in students such as lack of teamwork, engagements in social work, and gaps in students' physical and mental well-being. Further, a 79% proportion of the students has agreed that they have missed being with their peers. However, 6.5% disagree that they missed being with peers.

Further, 51% felt lonely during the pandemic, but 19.3% of students disagreed with the statement. This may be because students are not alone at home, with their parents and other family members. So, they have emotional support from the family when studying at home. However, this age group needs peer interaction for personal development and proper social well-being. Therefore, this new education experience will negatively impact students if there is a lack of social engagements and interactions. Nevertheless, these findings imply that most of the students have felt isolated and negative feelings while studying at home because of the rapid transition in the education system

The literature states that teachers' communication skills have a significant role in better performance of the students [42], and according to the findings of this study, 68.4% of students had agreed with the statement 'My lecturers were well prepared to provide instruction remotely'. During the pre-pandemic also in universities of Sri Lanka, e-learning systems were promoted, and students and lecturers were familiar with these techniques to a certain extent. Therefore, this sudden shift may not negatively affect the delivery of lessons via online portals. However, 25.3% of students had disagreed with the statement.

Supplementary to the finding, 46.9% agreed with the statement 'Teachers/lecturers were available when I needed help', meaning that lecturers were accessible for communication and asking questions for the students during the pandemic periods while studying remotely. This is important to facilitate the understanding of subject matters. Nevertheless, 15% disagreed with the statement. However, these findings prove that still university lecturers were well adapted for online teaching in the crisis period and were available for students when needed to contact most of the time.

Additionally, allocating time for students to engage in societies and other community-based activities via online platforms, aware students about online resources to improve their extra-curricular activities at home, conducting workshops in order to emphasize the importance of participatory activities and social engagements for students will benefit for their mental health and development.

4. Conclusions

The impact of the COVID-19 pandemic amplified many inequalities. Among the sectors, impacted by the pandemic, education is on top of the list due to its short- and long-term impacts on the whole world. This study discusses the impact on the education of engineering undergraduate students of Sri Lanka due to the COVID-19 pandemic, explicitly focusing on their experience with online education.

Students' participation in online classes was low initially, and it improved over time implying, that students were getting adapted to the new experience of learning despite the issues that arose. Most of the students had access to a digital device for their education. However, many students faced issues like device malfunctioning/power outages and sharing among family members when accessing their digital devices. Further, accessing a proper internet connection was also the main problem among undergraduate engineering students in Sri Lanka. Among them, connectivity problems, package limitations, inability to purchase an internet connection are the most common issues. From the findings, it was noted that nearly 50% of households' income have either stopped or reduced due to the pandemic, and that has a direct impact on accessing devices and network services.

Even though a supportive family environment improves engagement in education and motivates students towards the classwork, most Sri Lankan engineering undergraduates have issues related to the family environment. Among them, unavailability of a quiet place and someone to help, engaging in household activities, unable to concentrate on studies, and motivating themselves at home without their peers have been created issues when studying at home. Further, most students have negative feelings regarding learning at home, such as missing their peers, missing extra-curricular activities, feeling lonely, and feeling anxious about their studies.

This study focuses only on engineering undergraduates and should not be generalized for primary, secondary, and higher education levels and other disciplines. Thus, a research gap exists regarding the impact of COVID-19 on the education of different educational levels and disciplines in Sri Lanka in new waves of the pandemic periods.

5. Recommendations

Based on the findings of this study, the following recommendations were made:

1. Digital literacy is a requirement in the 21st century. Due to COVID-19, most students' digital literacy was improved, which is an advantage of the transition of the education system. However, conducting awareness programs regarding the use of new technological advances and proper use of digital devices and the internet is a timely need because of the misuse of these resources by students. Further, continuous digital literacy training will help keep competence on digital devices.
2. Income is a major socio-economic factor that will affect the education of the students, especially online education. Therefore, providing incentives to purchase digital devices and internet connections will improve the resource access of students with low income.

3. Development of the blended education system after proper curriculum investigation to face future COVID-19 like pandemic situations and simultaneously keep the digital literacy improving further.
4. Training programs for lecturers, instructors, and students to teach and learn via online platforms, making parents aware of online education and the importance of their support towards students' academic success, will exemplify online education.
5. Most of the students' mental health was negatively affected due to COVID-19. Considering the prevailing situation awareness programs for students about online resources to improve their extra-curricular activities at home, conducting workshops to emphasize the importance of participatory activities and social engagements will benefit their mental health and development.

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Informed Consent Statement: All subjects who contributed on this study participated on an entirely free and voluntary basis through an online form. The participants were informed that the data collected will be used for research and academic purposes only.

Data Availability Statement: The data presented in this study are openly available in Ilangarathna, Gayanthi (2022), "education sciences data", Mendeley Data, V1, doi:10.17632/pt3c9y4hb4.1, 5 January 2022.

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

Appendix A.

Appendix A.1. Impact on Education Due to COVID-19

This survey is conducted by the AI4COVID project group of the Faculty of Engineering, University of Peradeniya. The purpose of this survey is to collect data regarding the impact of COVID-19 on the education of engineering undergraduate students.

1. Select your university from the list
2. What is your residential district? (select from the list)
3. What is your ethnicity? (select from the list)
4. How often did you participate in a class in person? (Please answer considering the following pandemic periods)

Pandemic period	Never	Once a week	Few days a week	All the time I have classes
Post first wave				
Second wave				

5. How often did you participate to a class online? (Please answer considering the following pandemic periods)?

Pandemic period	Never	Once a week	A few days a week	All the time I have classes
First wave				
Post first wave				
Second wave				

6. Compared to a typical week in pre-pandemic period how did you feel about your studies each week?

Pandemic period	I learned less	I learned about as much	I learnt more
First wave			
Post first wave			
Second wave			

7. Did you learn something extra (following online courses, playing instruments, cooking...etc.) during the following periods?

Pandemic period	Yes	No
First wave		
Post first wave		
Second wave		

8. What would you prefer more?

In person Classes
Online classes
Mixes of online and in person classes

9. What is/are the device(s) used for learning? (select all related)

Type of device
Mobile phone
Laptop
Computer
Tablet
Device use by another family member
I do not have a device for my studies
Other(specify)

10. Did you face following problems when accessing a device?

Issues
No device
Had to share among family members
Device malfunctioning/power outages
No issue
Other (specify)

11. What are the problems you faced when accessing internet connections?

Issues
Connectivity issue (signal strength issue)
Unable to purchase the service
Package limitations
Internet traffic issues
No issue
Other (specify)

12. What are the problems you faced when studying at home? (Please select all applicable)

Issues
Problems with finding a quiet place to study
Problems with finding time to study because I had household responsibilities
Problems with finding someone who could help me with my studies
Problems with motivating myself to do school work
No Issues/ Problems
Other (specify)

13. State whether you agree/disagree/neutral for the following statements

	Agree	Neutral	Disagree
I felt lonely			
I enjoyed learning by myself			
Teachers/lecturers were available when I needed help (eg: through virtual office hours, email, chat) compared to the period before the pandemic			
I feel anxious about schoolwork			
I was motivated to work			
My teachers/lecturers were well prepared to provide instruction remotely			
I miss extra-curricular activities organized in my school/institute			
I miss being with my peers			

Appendix A.2. Impact on Household Income

14. Which of the following category includes your average monthly household income during the following time periods?

Pandemic period	<25,000	25,000–50,000	50,000–80,000	>80,000
First wave				
Post first wave				
Second wave				

15. Compared to pre-COVID situation, did your family income changed during the following pandemic periods?

Pandemic period	Income increased	Income reduced	Income stopped	No change in income	No idea
First wave					
Post first wave					
Second wave					

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