Impact of COVID-19 on Introductory Engineering Units: When is the Right Time to Fully Adapt Online Education on a Long Term Basis?

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CONTEXT

COVID-19 pandemic is a health crisis that has affected every university around the globe. To join the national efforts for slowing community transmission of COVID-19, universities rapidly moved on-campus operations to online delivery. The pandemic circumstances caused particular complexity in teaching fundamental engineering units such as statics, dynamics, and fluid mechanics. Not being able to attend the classes for students potentially reduced engagement and carried a risk of students not having the opportunity to properly assimilate introductory engineering concepts.

PURPOSE

This paper acts to provide an understanding of the effect of the COVID-19 pandemic on students' performances in online classes of introductory engineering units. This study will assess the potential challenges in delivering these units online and how to consider online delivery as a more viable option for presenting these units in the future.

APPROACH

A carefully designed survey was used to analyse student performance in online units. Besides, direct interviews with lecturers and evaluation of the students' final assessment in cases of online and face-to-face teaching were considered.

OUTCOMES

Our study shows that the current format of presenting the online units reduced the students' engagement and led to student's anxiety and a lack of confidence. However, designing the unit deliveries and assessments, particularly for the online environments, may enhance the students learning and performance in the long term.

CONCLUSIONS

Designing the introductory engineering units for online delivery is an entirely different practice. The university lectures need to adopt the full capacity of state-of-the-art online technologies to reduce the anxiety and lack of confidence in university students. The lack of digital creative skills in the engineering education sector requires more professional development opportunities by universities to use introductory engineering units' online delivery.

KEYWORDS

Online delivery, Introductory Engineering Units, Educational Success

1. Introduction

The Covid-19 pandemic has disrupted universities across the world primarily by shifting the traditional in-class face-to-face teaching practice to emergency remote teaching delivery. With the short notice from the governments, universities, and many thousands of faculty members started preparing for online teaching, and the students followed the new instruction for distance education via different online resources (Bao, 2020). However, this transition to online learning was not necessarily smooth as students have experienced various challenges during this period. This includes the adoption of online resources, missing campus facilities such as laboratories and libraries, maintaining student's motivation, cost of required new facilities, and less peer support (Rost, 2019; Langella, 2020). At the same time, lack of support in terms of human resources and facilities, a lack of the physical environment for lecturers to express their concern and support to the students, adopting new online technologies to present a unit, and providing practical assessment are some of the significant challenges faced by academics (Kumar, 2010; Rost, 2019). Simultaneously, more control over an individual learning situation, more flexibility in terms of time and place, and easier access to a large amount of information are a few advantages of e-learning (Arkurful and Abaidoo, 2014).

The growth of e-learning is expanding immensely (Rana et al., 2014); however, in reality, some subjects are much harder to transfer online. The fundamental engineering units, such as statics, solid mechanics, dynamics, and fluid mechanics, are traditionally known to be challenging for most students to learn and for lecturers to deliver the concepts. These units require the students to have a strong foundation and be highly adaptive with fundamental abstractions of maths and physics. Consequently, as the backbone of the engineering degrees, these units help students have better retention of knowledge and create a strong foundation for more advanced level engineering units. A lack of knowledge or understanding of the theory and concepts in these units can negatively impact the knowledge of technical engineering units and a shortage of confidence in the engineering graduates entering the job markets. Moreover, these units are usually taught in the first and second years of engineering degrees, where students are experiencing the transition from high schools to universities. The situation had also added extra tension on students and teachers due to uncertainties that were raised due to adaption to demands of university-level education and a new, more independent lifestyle for the majority of students (Mahroogi et al., 2015).

The significant reform in the education system occurring in the short term is a reminder that there is a need for the transformation of educational interference in the longer-term (India Today, 2020). Although full online delivery of the introductory engineering units is still challenging, the current condition provides an opportunity to check the adoption of online learning to persist post-pandemic and how such a shift may impact engineering education in the future. Usually, it is noted that generation Y (millennials) are supportive of technology interfaces. Hence a thorough investigation of the potential risk and/or the potential opportunities that such a sudden change due to pandemic have created can help clarify what is likely to occur as we move forward to e-learning in engineering education.

This paper aims to study the effects of online learning of introductory engineering units on students' performances. For assessment of these performances, students' feedback on online learning, interviews with the lecturers, and evaluation of the final assessment (grades) are considered.

2. Methodology

This study aims to determine whether the use of e-learning in introductory engineering units affects students' motivation and impacts their overall performance. The statistical population considered in this study includes students in the first and second years of engineering degrees at Macquarie University and the University of Tasmania. These students are enrolled in one of the introductory engineering units such as Statics, Mechanics of Solids, or Fluid Mechanics. An expert-designed questionnaire of 20 questions was shared with the students. These questions included two parts: (i) demographic survey questions (age, gender, nationality, living

status, etc.) (ii) technical questions were mostly designed according to 5-point Linkert scales (from 1 = strongly disagree to 5 = strongly agree). As this study involved human subjects, a human research ethics approval was obtained from the Faculty of Science and Engineering Ethics Subcommittee at Macquarie University (Ethics Ref No: 52020676617213), which confirms this research meets the requirements set out in the National Statement on Ethical Conduct in Human Research 2007 (updated July 2018). As a case study, the final results (students' grades) for one of the units in 2019 and 2020 were analysed for comparison purposes. It should be noted that the selected unit was delivered face-to-face in 2019; however, due to COVID-19, it was delivered fully online in 2020. The unit codes and the names of the lecturers and student participants are not presented in the paper due to confidentiality. The t-test using Minitab 18 statistical software was used to check the difference between the final assessment results in the aforementioned years. Finally, direct interviews with the lecturers of the units were considered to receive their feedback on the pros and cons of adopting the fully online delivery of the units and impacts of the students' performance.

3. Results and Discussions

In total, 41 students participated in this survey (20% survey participation rate), 7% were female, and the rest were male candidates. This is consistent with the ratio between female and male students in most engineering units, which only have a small fraction of female participants (Bolton, 2019). It was found that 66.7% of the students had no prior experience in taking any online units, this being their first experience, and the rest of the student cohort had some experience taking one or more online units during their education. Although there is strong motivation around the world for creating a fully online learning environment (Selvi, 2010; Stone, 2019) or hybrid formats (Dizon et al., 2018) in the past decade, online learning is not yet the regular practice experienced in the Australian education system. Therefore, this is a new experience for many students, particularly those starting their first- and second-year engineering degrees in 2019 or 2020.

Among the participants, 22.2% of the students were living on their own and the rest of the participants were living with family, friends, or classmates. Although people may have different living styles, a quiet and comfortable learning space is essential for online learning education. 75% of the participants were domestic students (Australian citizens or permanent residents) and the rest were international students. Bearing in mind that most of the international students often live away from family for the first time, and they sometimes suffer homesickness and anxiety, particularly due to the lockdown condition, poor eating habits, and money worries. These factors may have directly impacted their educational performance and level of their stress (The Conversation, 2018; Datta, 2020). As acknowledged by Sun (2016), the cultural barriers to e-learning are more than the technology barriers (Sun, 2016). Fitting into a foreign classroom is a difficult experience for most international students, particularly in the online environment. Moreover, regularly asking questions and sharing thoughts is not a common practice for many international students. Consequently, if the lecturers do not practice different proactive approaches in engaging all of the students in the interactive learning process, they may feel more isolated and unmotivated. On the other hand, allocating students to different groups and the use of collaborative tools to engage them was not an easy approach for most of the introductory engineering units that had 50+ students, and sometimes more than a hundred students in a classroom. Hence, more innovative tools and practices require to be developed to engage all students in an online classroom. Moreover, when lectures considered live events such as webinars and/or online group discussions, the language was another barrier for international students to fully participate in different activities. Many of these students were feeling shy, remained quiet, and felt uncomfortable speaking as a second language speaker while watched by the lecturer and other classmates. In particular for international students, some of the effective alternatives include (i) using online forum options that allow the students to ask their questions from their peers and lecturers and (ii) recoding the online activities to be repeated for the students as often as they prefer.

The collected data showed 55.6% of the participants were students only at university (no other simultaneous occupation), and 38.9% were also working part-time in addition to their university education (5.5% did not define). Part-time work is one of the factors that affect students' academic achievement; however, some of the students financially rely on their savings or other forms of support (Muluk, 2017). No doubt, online education provided more flexibility for students who would like to work simultaneously. However, this flexibility may sometimes negatively impact their performance if the students do not have proper time management skills and abilities to prioritize their time. The previous research confirms half of the university students have a moderate to low-level time management score (Khanam et al., 2017). Time management and priority-based structuring of time allocation is a skill that students gradually need to attain, and many students are suffering, particularly at the beginning of university education.

Anxiety about understanding their study, particularly for the introductory engineering units with complex maths and physics, is one of the challenges faced by the students. As demonstrated in Figure 1, 77.8% of the students were concerned about understanding these fundamental units when they were delivering online. Breaking the unit assessments into smaller tasks and providing continuous feedback to the individual students can reduce this anxiety. Previous feedback from college students showed that the level of anxiety in students about understanding the contents in a unit is linked with the loss of their motivation in online classes (Chen, 2020). It is important lecturers consider timely response and feedback, be regularly available to the students, and have periodic communication with students to remind them what is expected from them to reduce their anxiety (Martin et al., 2019). Adopting new technologies may lead to anxiety in both lecturers and students as well (Johnson, 2012). Accordingly, presenting the contents of a unit with the user-friendly tools that are accessible to all students can easily be adapted and give more confidence to the students.

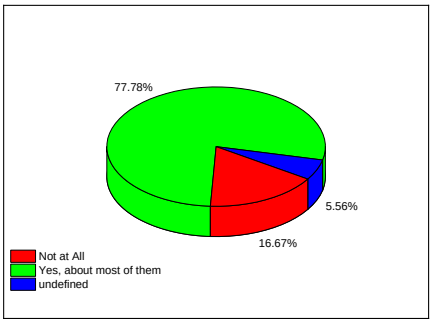
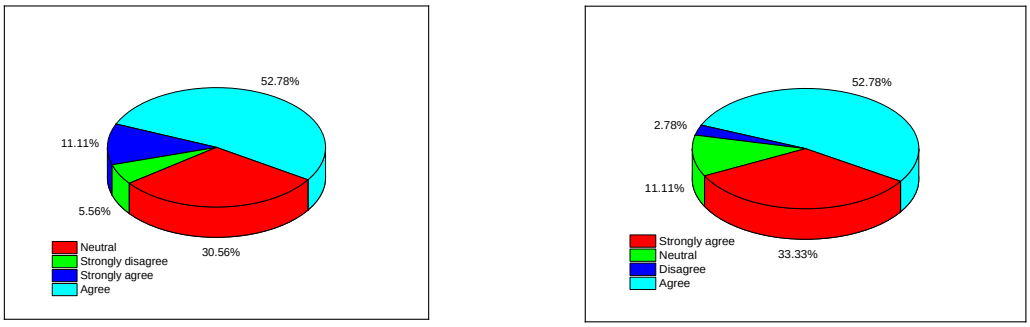


Figure 1: Percentage of students who feel anxious about understanding the contents in the unit

As noted in Figure 2, since the universities moved to present the units online on short notice due to the pandemic condition, communications started rapidly with students and lecturers at different levels of the university management hierarchy, with more than 60% of participants finding this effective to understand the process. Similarly, this was true with the communications between the lecturers and students to provide a clear pathway about the practice of the future units' deliveries, expectations, and assessments. This was done by using different online platforms (iLearn, Mylo, Email, etc.) as the main communication channels between lecturers and students. The pandemic situation and the subsequent changes at short notice reaffirm the need for the universities and lectures to have a better communication management plan, particularly for emergency conditions. It also required the lecturers to have alternative plans and flexibility to shift the modes of their teaching and transparently communicate with the students at short notice. Questions from the students such as "what to do", "how lecturers want them to do it", "how to attend the lectures" and "how to get feedback on their work" needed to be communicated with the students (Moore and Hodges, 2020). Moreover, lecturers needed to be more responsive to urgent needs or questions from the students which added extra load on the lecturers during these conditions.

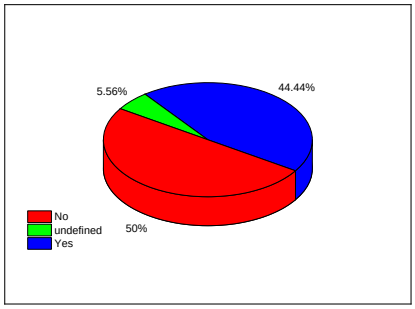


(a) (b)

Figure 2: Percentage of the students who believe/or not the communication from the (a) university and (b) units' lecturers were effective during institutions lockdown due to the pandemic

It was important to note that 50% of the participants did not find the classes engaging. Although students' engagement in the introductory engineering units such as statics and fluid mechanics is an ongoing challenge for the lecturers before the pandemic condition, this became more critical during the online classes. Engaging students in the units was challenging for the lecturers as well, and as mentioned by one of the lecturers, "From a teaching point of view, it takes at least twice as long to deliver online as you are often explaining things multiple times to different people, it is much slower for students to ask questions and it is much harder for teaching staff to determine if the student is grasping a concept when you are teaching it because you are just talking to a bunch of names on a page that sit there on mute and say nothing". These units are based on the fundamentals of mathematics and physics, and lecturers are mostly the sole presenters in the classrooms to describe the basics and solving examples for the students. Recently, the application of project-based learning practice for contributing the students' motivation and engagement is taking attention to delivering these units (Rios et al., 2010; Cunningham and Lachapelle, 2016). However, using the practical facilities in an online environment is another layer of challenge that needs to be restructured, allowing the unit to fit with the new environment. As mentioned by one of the lecturers, the practical project in the unit was severely damaged, as it was designed for the physical lab, and students could not do it in online mode. The application of virtual labs (Bengrut, 2020) is an alternative that can be considered by the lectures in these fundamental units to engage the students in more practical applications. However, this method requires developing a user-friendly interactive interface to improve students learning experience and additional multi-media files helping students to do the necessary experiments individually or in a team. Using Virtual Reality (VR) facilities is another option helping to better facilitate students' learning where they can better observe the practical applications of the theoretical knowledge acquired in their studies. Moreover, the use of VR facilities to simulate real-field interdisciplinary industrial projects enhances students' teamwork, working in interdisciplinary groups, and time management (Hafner et al., 2013). As illustrated in Figure 3(b), more than half of the participants were not sure and disagree that traditional lectures in the online environment are sufficient to understand the practical applications of theories taught in the units.

As illustrated in Figure 4(a), less than 50% of the participants agreed or strongly believed changing to the online mode of teaching at the beginning of the semester due to the pandemic conditions may negatively affect their final performance in the selected units. 66% of the students' cohort believed that they could perform better if they continued to have face-to-face classes (Figure 4(b)).



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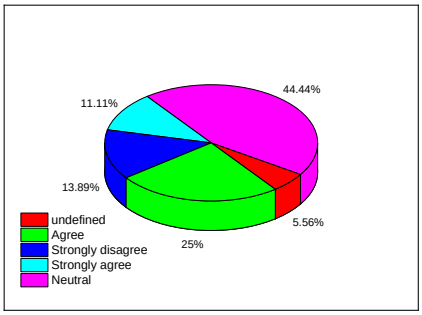
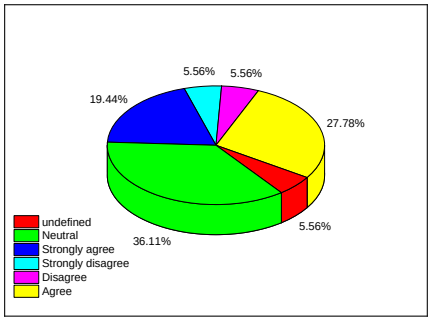


(b)

Figure 3: (a) Percentage of participants found the classes' mode (online) to be engaging (b) Percentage of students believe the online delivery of units useful in understanding the practical engineering issues in applying the theories learned

Moreover, 70% of the students preferred to participate in traditional face-to-face lectures and tutorials for these units. However, the outcomes of the responses are in contradiction with the final assessment results in these units. The comparison between the final grades in one of the units, as a sample by using a two-sample t-test with a 90% confidence interval, confirms a significant difference between the two years 2019 and 2020. The failure rate in this unit is 5% less in comparison with the one reported for a similar unit in 2019 in which the students had face-to-face lectures and tutorials. Additionally, the rates of the students who received distinction (D) and high distinction (HD) were also higher. Thus, the comparison of the final results between two years confirms the better performance of the students in the year having the online teaching mode. It should be noted that the lecturer of the unit in both years was the same, and there were no marginal changes in the unit outlines. Some of the lecturers believed less invigilation possibility is one of the main reasons for better performance in online exams, but this is not the entire case. Although, it is believed the assessment tasks should also be restructured and prepared for the online units as well.



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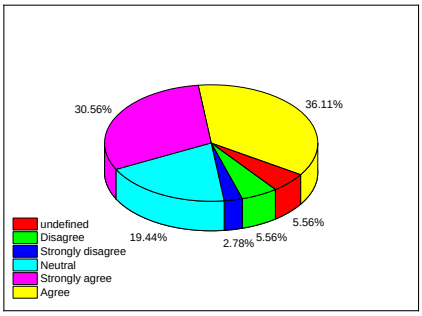

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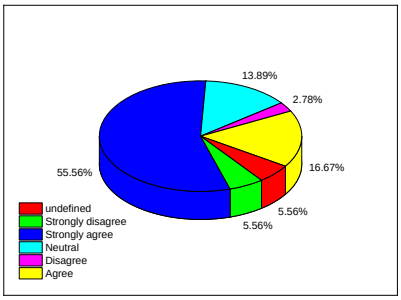

(C)

Figure 4: (a) Percentage of students who believe this mode of learning adversely impacted their final performance (b) Percentage of students who think they could perform better if they had similar classes face-to-face (C) Percentage of students preferring face-to-face lectures and tutorials instead of online activities

The unfamiliarity with the online teaching environment is one of the main reasons that affected the confidence of the students and led to underestimating their performance in these units. Providing more clarity in online units with a consistent direction and providing easy access to support services may enhance students' confidence, focus, and motivation. Dividing the students into smaller groups and lecturers and other support staff (e.g. tutors) having more direct contact with the individuals to discuss the potential challenges can present a clearer picture around the technical concepts of the units and it is also a good strategy to build the students confidence.

Overall, there is no doubt that the online teaching environment for delivering fundamental engineering units has different advantages. However, the structures and delivery of the units need to specifically plan for the online environment. This was also reflected in the students' comments: "I think the unit needs to be structured purely for online, rather than adapted to it - for the most successful impact on the students learning". Hence, in the current format, some of the students preferred to have fully face-to-face or mixed-mode lectures and tutorials which could be more engaging: "Just the theory is incredibly difficult to understand in online lectures. Having face to face or some sort of individual contact can help the students understand vital information" (comment from one of the student participants). Developing interactive online learning activities in different engineering units is not an easy task and needs the ongoing support and training of the lecturers in these units. It is believed that many engineering lecturers are reluctant to present the online units due to the lack of knowledge concerning online teaching methods, fear of a heavy work burden associated with the online activities, the fear that students' achievements might fall and damage the university's reputation. Lecturers believe support from the IT department, training tutors for online teaching, and access to tech facilities are needed to enhance the quality of online unit deliveries in the future. All of the participating lecturers mentioned their workload was dramatically increased to achieve satisfactory results. For adopting the online mode for the introductory engineering units in the future, lecturers require to also enhance their IT skills (e.g. skills to use graphics, videos, and digital audio files), have more technological literacy, and improve their time management skills (Resilient Educator, 2020). Improving these skills requires more collaboration with peers at different universities, sharing ideas across the universities in informal and formal activities, and using ongoing mentors who have experience in online education delivery.

4. Conclusions

The feedback from lecturers and students in this study reveals that for delivering successful online fundamental engineering units, the following aspects need to be considered by universities:

- Online learning is an entirely different mode of delivering the units than face-to-face practice, so it needs to be designed differently based on its delivery method. Lectures involved in this study believed that only recording face-to-face lectures and sharing them with the students might not be an effective practice.
- Universities and lecturers should re-think the alternative plans for delivering the units while developing the curricula of different programs for the included units. Various methods for communicating the changes in the unit's deliveries need to be thought and considered in advance to avoid students' confusion and anxiety in emergency conditions.
- Adopting the full capacity of the online technologies could help students in active learning and enhance students' performance and motivation. The use of virtual labs, VR facilities, interactive videos, and presentations will help to enhance students'

engagement in the online units and help them to better see the practical applications of technical concepts in these units.

- Unfamiliarity with online learning environments may lead to anxiety and a lack of confidence in many university students, according to this study. Therefore, presenting a clear picture of different aspects of a unit delivery, such as expectations from the students in a unit and assessment tasks, is helpful to enhance the confidence of the students and improve their learning performance.
- There is a lack of digital creative skills in the education sector, and it is required to present the opportunities for the professional development of skills to create graphics, video, and quality audio files. Universities will need to provide more training for lecturers, particularly for those teaching engineering introductory units that typically handle a large number of students from different engineering disciplines. This will help to enhance the lecturers' knowledge concerning online teaching techniques, manage the heavy work burden, and help them actively assess and manage students' performance and achievements during the semester.

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