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Exploring Teaching and Learning Experience during COVID-19 Pandemic in Engineering Education

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Abstract: The education system is continuously modernizing by accommodating the need due to the industrial revolution. Various teaching modes are also introduced including a diverse range of students, particularly in engineering education. The COVID-19 pandemic has disrupted normal education worldwide, forced to shut down campus activity for an extended period which forced Universities to adopt alternative approaches to continue student's academic year. Engineering education faced significant challenges to find a realistic substitution for lab-based hands-on activity as well as group or team-based learning experiences. It is therefore very important to know the challenges and ways to address them. This paper evaluates the teaching and learning experiences observed in engineering education in Australia and abroad during the COVID-19 period compared to the pre-COVID period. The key motivation of this study is to identify key challenges arises due to COVID-19, develop Teaching & Learning (T & L) approaches to address these challenges and evaluate the effectiveness of the applied changes in the T & L approach, identify shortcomings, and find ways to improve them. The student feedback on selected engineering units have been collected from Deakin and Murdoch university in Australia to evaluate the performances of the applied changes. This data is considered as an authentic source of information to compare and identify the key challenges and effectiveness for students' learning in pre-COVID and during COVID condition. This study later explored various literatures to gather experiences from other universities across the globe and by analysing all findings including academic experiences finally developed constructive recommendations for improvement. It is found that the current form of online mode of teaching has room to improve further as one segment of students finds it challenging and some others like a few approaches. It is also found that the online infrastructure, staff skills to innovate new unit designs, and motivating students are the other challenging areas. Therefore, a new teaching and learning framework is required to overcome all the challenges for future learning.

Keywords: learning experience; online method; cloud campus; teaching evaluation; COVID-19

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1. Introduction

It is over 2000 years; people are trying to understand learning and teaching methods. Modern vocational education and apprenticeship methods are an example of the Roman approach to education. The teaching and learning process gradually evolved into the current stage. Linda Darling-Hammond et al. described various learning theories and teaching practices [1]. Effective teaching involves: (i) organizing the learning environment, (ii) organizing knowledge, information, and activities, and (iii) organizing people [1]. Following these, the modern education system operates in principle as an interactive face-to-face method where students can make queries, participate in the discussion, conducting lab experiments to clear their learning. The interaction also includes the learning environment which includes working with other students, using lab instruments, accessing library resources, engaging in sports and social/cultural activities to grow in a holistic

way, and be ready for the challenges in the future workplace. Educational institutions such as engineering universities are required to ensure effective learning environments for the students with adequate support from the academic and technical staff. The adult and diverse backgrounds of students are increasing in tertiary education, particularly in Australian universities. The key challenge of this non-traditional cohort is their social, family, and professional commitment which leads them to be off-campus [2], and universities are offering various modes of distance and blended learning by utilising advanced online teaching tools. The commonly used tools for online or blended teaching are: Blackboard, Canvas, Moodle that provides a virtual learning environment for some specific learning tasks to the off-campus students in synchronous mode when students attend in real-time and/or listen the recordings in asynchronous mode at different time [3].

With the growing technological advancements and considering the special needs of some specific students group, several institutes are adopting appropriate technologies [4] to provide some form of remote learning environment for them [5] in parallel with the face-to-face mode. The remote learning environment requires additional capabilities on all sides of the learning system such as the university required to provide resources, technical and technological facilities, skilled academic staff, and students. Remote learning is more challenging for engineering courses as students learn theory and concepts in the classroom which are required to validate through lab experiments [6] that enables them to develop real-world problem-solving skills. Authors in [7] developed remote labs for mechanical engineering education and to overcome its limitations a virtual representation of the lab with experimental facility was also developed.

The global outbreak of the COVID-19 pandemic has spread worldwide in 2020 and affected almost all countries. This pandemic has affected not only the health sector but also all sectors including education [8]. The lockdown, social distancing, and restriction measures have significantly affected the education system in 2020. The academic progress was suddenly disrupted, and more than 220 million tertiary students were affected in 2020 due to restrictions and university campus closures [9]. This disruption continues in 2021 also. The term “work from home or teach from home” has become very familiar in recent times. The education system has suddenly shifted from classic face-to-face teaching philosophy to online or remote or distance learning mode [10]. Although online or distance learning is known to the academic community, however, the biggest challenge for engineering education is to transform all the face-to-face learning activities into online mode. Moreover, adapting to various online tools is also challenging. Authors in [11] mentioned that, the socioeconomic status of students, cultural heritage, and learning environment are the key influential issues of e-learning or online learning for international students in Australia. The authors also suggest improving e-learning design considering the importance of international students for Australian universities.

This paper aimed to investigate the impacts of COVID-19 in engineering education and analyses the implemented online approach in two different setting environments in Australia. This study also explored impacts and issues with online education in different other countries. The key observations with recommendations are summarised for a better learning environment. Section 2 lists COVID-19 challenges observed in two states of Australia, Section 3 explains the applied approach in two undergraduate engineering units in two universities in Australia. Section 4 discusses the effectiveness of the applied approach while Section 5 summarises the impacts observed in different other countries and compiles their suggestions or actions to address it. Section 6 summarises the observations as key findings with proposed recommendations while Section 7 presents the conclusions of the paper.

2. COVID-19 Impacts on Education in Australia

Tertiary education in Australia is highly represented by the presence of international students from all over the world. When the travel restriction was announced in March 2020, the arrival of international students falls significantly from April 2020 [12]. The

COVID-19 impact and response are not uniform in all states and territories in Australia. From 25 January 2020 until 30 July 2021 total of 33,909 cases were recorded in Australia. However, when the highly transmissible Omicron variant spread in late November 2021 the COVID-19 cases sharply rise in Australia, particularly in New South Wales (NSW) and Victoria (VIC). As of 12 February 2022, a total of 2,505,939 cases were recorded in Australia. The state VIC recorded 936,671 of the total cases and experienced 2266 deaths from a total of 4546 deaths in Australia [13]. VIC experienced the almost entire year 2020 either state-wise or partial lockdown which impacted all levels of academic study during the year 2020 and all Victorian university campuses also remained closed which continued in 2021 as well. Compared to VIC, other Australian states experienced less impact, particularly the universities in Western Australia (WA) and their undergraduate studies were not impacted like VIC. It is important to note that, due to border restrictions, a good number of international students were stranded overseas, and the normal on-campus students were unable to attend the campus normally which impacted the normal learning process seriously. Hence, universities took various steps to continue the student's academic progress.

The main student cohort in an undergraduate course at Deakin University is the on-campus students which also includes a good number of international students. Moreover, a good number of students enroll in Deakin from remote or distant locations, and they are treated as Cloud campus students. Due to restrictions, the stranded overseas students, and the normal on-campus students were unable to attend the campus which impacted their normal learning process. Deakin has a strong infrastructure for Cloud campus students, however normally, the Cloud campus students have some specific on-campus intensive activity which is also impacted due to the COVID-19 lockdown in 2020 and later extended in 2021. Timely initiatives have been taken by Deakin University to continue the Trimester-2 (T2) in 2020, although face-to-face activities had to drop, which followed in most of the year 2021 as well.

The Murdoch University in WA has a strong presence of domestic students in addition to international students in their undergraduate engineering courses. WA has not been impacted severely like VIC, however, to ensure health, safety, well-being, and consistency with the government advice, Murdoch University has taken many initiatives in their teaching and learning. Most of the engineering units in Semester-2 (S2) 2020, were run in mixed/hybrid mode including online/virtual Lectures, face-to-face (where possible, ensuring all restrictions by the state government), and/or online/virtual Workshops and Laboratories. Although the condition in 2021 was better than 2020 however, due to strong border restrictions, the 2020 like teaching and learning approaches were followed in 2021 as few students were locked in either overseas or in the other states of Australia.

To address the impact on students and their learning, different universities in Australia took different measures based on the local government COVID response policy. Considering two different scenarios mentioned above, this study explores to understand the COVID-19 impact response on the updated study method in a comparative way from one university in VIC and one in WA. The effectiveness of the applied approach has been evaluated through student unit satisfaction feedback for the respective units in the 2020 and 2021 academic years in comparison to the pre-COVID academic year.

3. Framework or Working Approach

Considering the severity of the pandemic and to comply with the government's COVID-19 response policy the universities quickly shifted to the digital platform in 2020. This transition is not easy, and it is very difficult to translate all on-campus activities into an online mode within a short period of time. On-campus T & L activity is not only just delivering lecture or attending routine activities, it also includes maintaining cohesive learning environment such as; discussion, participating in group work, sharing and developing friendships, attending various cultural and sporting events and many more as shown in Figure 1. Figure 1 also shows that the transition happened in 2020

where some key on-campus attributes are lost in online mode or translated into new forms of digital activities. Moreover, many academic staffs are also puzzled as the need came suddenly with very limited time and limited resources to translate activities such as lab, group work, assessment, feedback, and engagement to ensure better learning. Moreover, there was no timely literature available that could help in the knowledge domain to the academics in 2020 as the COVID-19 is the first of its kind. Authors in [14] conducted a study on academics training programs among lecturers from Catalan universities in Spain and found that during COVID-19 in 2020 the training need rises for online teaching, learning institutional digital tools, online assessment and design of online courses. The lack of time for adapting with online system and complexity of online evaluation are the key difficulties observed. The study [15] found that students in their first year at university are not satisfied with the online teaching in restricted period as their interaction with academics and access to the resources are more important. Another study [16] from 20 universities in Spain shows that students in their first year requires tutoring, emotional support and academic interactions for quality education. The teaching material, teaching platform are also found very important and for this academics training on digital competences are required. Authors in [17] compared three teaching modes: face-to-face (F2F), emergency remote teaching (ERT) and smart classroom (SC). They found that ERT, SC are more effective solution under pandemic like situation although they acknowledged that these modes have issues in teamwork and effective interactions. Similarly, authors in [18] finds that majority of the students were not satisfied with the quality of online education that was enforced during lockdown which negatively affected their academic performance, which then affects their mental health. Similar concerns also expressed in [19] by students about lack of social support, security and students' employment. Authors suggested that correct adaptation with online learning, enabling effective communication among students and with academics can improve students' emotional state.

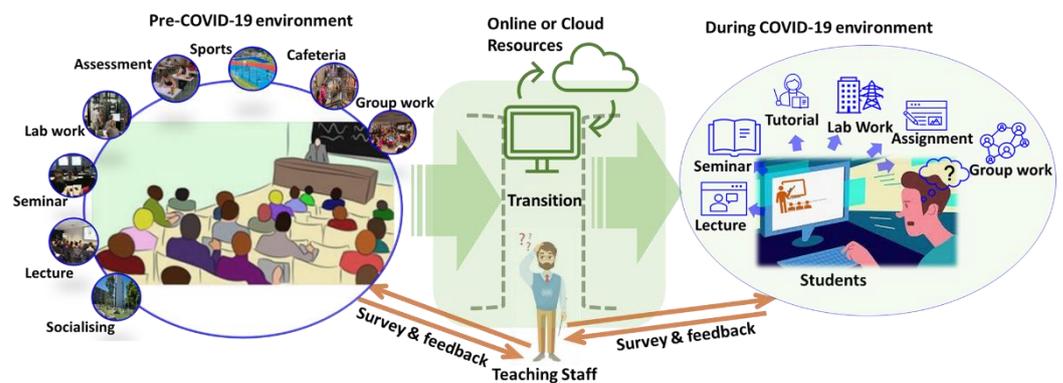


Figure 1. The process of transition from face-to-face to online teaching mode.

Considering the above-mentioned constraints, this study modified/updated one 3rd year undergraduate electrical unit (Unit-A) at Deakin University and one 2nd year electrical unit (Unit-B) at Murdoch University in early 2020 to deliver during COVID period. Considering unit learning objectives, available online facilities, and learning resources, these two units are significantly modified to convert into completely online/virtual mode and/or hybrid/mixed mode (combination of online/virtual and face-to-face). The transition of these units from the pre-COVID (2018 & 2019) to the COVID period (2020 & 2021) is illustrated in Figure 2.

To adjust with the COVID condition all modes of students at Deakin University in 2020 are treated as Cloud only students. It is a significant challenge to most of the courses, particularly for engineering courses where lab experience is an essential learning component. Similarly, all teaching and learning resources are transformed into a form that students can access anytime they need. As stated earlier, the selected Unit-A runs based on a project-based learning approach. Therefore, this unit requires extensive engagement in

the learning stages which include individual and group work, compulsory lab work, and software tools to design and test the work. This unit has 5 assessment tasks: topic tests, project reports, Lab experiments, and reports, including self and peer assessments. The other selected Unit-B has also 5 assessments: mid-semester test, project presentation and demonstration, project report, Lab experiments, and final exam. Both the units have weekly lectures and Seminars/workshops and compulsory extensive laboratory experiments.

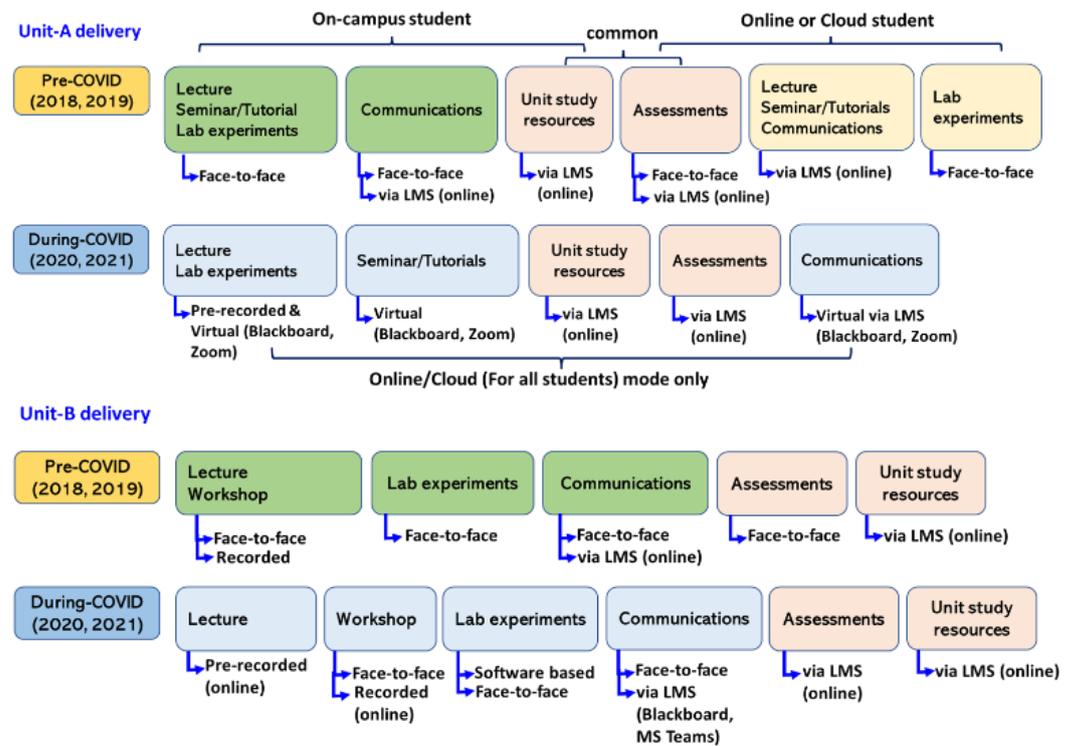


Figure 2. Learning activities in pre and during COVID situation in the two studied units.

To implement the changes highlighted in Figure 2, all lectures, tutorials are converted to recorded videos, and a virtual classroom is designed using various tools such as Blackboard Collaborate, MS Teams, and Zoom. The key challenge is to deliver the lab experiments in online mode and consider various alternative options such as; virtual labs using LVSim, or software simulation using Matlab, PSS/Sincal, or PowerFactory. But the specialized electrical engineering lab to test faults in the power system in Unit-A cannot be converted to any of those forms. Therefore, an alternative approach is applied by video recording labs to capture the learning events in detail with sufficient explanations, all events data are recorded and shared with the students to analyse the findings for their learning.

This paper compares the unit performance by evaluating students' feedback in 2020 with the pre-COVID period (2018–2019) feedback to identify the effect of changes on students. The student feedback in 2020 was considered to update further to deliver the unit in 2021. To justify the effectiveness and acceptance of the changed/updated approach in 2021 this paper also analysed a number of existing studies through an extensive literature survey on the relevant issues and compared the approaches taken by universities around the globe to manage the challenges/barriers they faced. Considering all the findings a critical judgment was applied to list the key observations and proposed recommendations for delivering engineering education more effectively in the future. The complete process of this research or the method of this study is clearly illustrated in Figure 3, which shows the pre-COVID and during COVID unit delivery challenges, scopes and compared it with the challenges faced by other universities and analysed all findings to develop the recommendations.

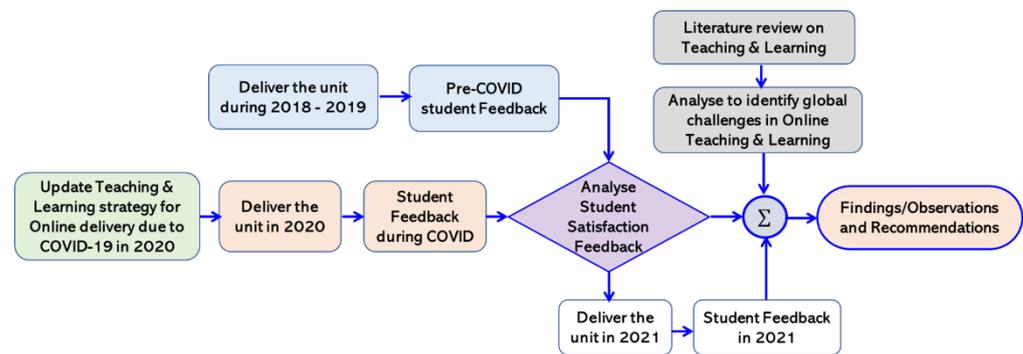


Figure 3. Step by step methodological approach of the study.

4. Effectiveness of the Applied Approach

The updated unit delivery mode is applied in 2020 and students provided feedback upon completing the unit. The questions used in the unit evaluation feedback at Deakin and Murdoch University are shown in Figures 4 and 5 respectively. Student responded to the questions by selecting any of the five different answer options such as, strongly disagree (SD), disagree (D), agree (A), strongly agree (SA) and unable to judge (UJ). Students' responses to these questions are therefore considered an authentic and effective source to know the first level of information on the student experience. There are 11 questions for Unit-A and 8 and 6 questions for Unit-B in 2018-19 and 2020-21 respectively. The student's response to these questions is compared with the pre-COVID response in 2018 & 2019 for the same units to identify the impacts of the new mode of teaching in their learning process.

Deakin University, Victoria, Australia, Student satisfaction Survey Questions in 2018 - 2021
Q1: The learning outcomes in this unit are clearly identified
Q2: The learning experiences in this unit help me to achieve the learning outcomes
Q3: The learning resources in this unit help me to achieve the learning outcomes
Q4: The assessment tasks in this unit evaluate my achievement on learning outcomes
Q5: Feedback on my work in this unit helps me to achieve the learning outcomes
Q6: The workload in this unit is appropriate to the achievement of the learning outcomes
Q7: The quality of teaching in this unit helps me to achieve the learning outcomes
Q8: I am motivated to achieve the learning outcomes in this unit
Q9: I make best use of the learning experiences in this unit
Q10: I think about how I can learn more effectively in this unit
Q11: Overall, I am satisfied with the unit

Figure 4. The Unit-A evaluation questions Deakin university.

Murdoch University, Perth, Australia, Student satisfaction Survey Questions	
Question in 2018-2019	*Question in 2020-2021
Q1: It was clear what I was expected to learn in this unit	Q1: I received clear explanations on the unit tasks and assessments (previous Q1, Q2)
Q2: The assessment tasks were appropriate to the learning objectives	Q2: I received feedback that helped me to learn (previous Q3)
Q3: The feedback on my marked work was useful for my learning in this unit	Q3: I found the assessment tasks relevant to the unit content (previous Q4)
Q4: The assessment tasks tested my understanding of the subject are, rather than just memory	Q4: I was actively engaged in learning activities (previous Q5, Q6)
Q5: Activities in this unit helped me to achieve learning objectives	Q5: I was satisfied with the level of support from staff (previous Q7)
Q6: The unit resources were useful for my learning in this unit	Q6: Overall, I was satisfied with the quality of this unit (previous Q8)
Q7: I was satisfied with the level of support from staff in this unit	
Q8: Overall, I was satisfied with the quality of this unit	

* The 6 questions in 2020-21 are matched with the 8 questions in 2018, 2019 for analysis as shown highlighted with matched questions in blue and green colour

Figure 5. The Unit-B evaluation questions Murdoch university.

As indicated in Section 3 that all learning resources were converted to online mode for Unit-A, therefore the changes are also required for assessment styles. The assessments were converted to online open-book tests, quizzes, and reports. Lab experiments were transformed into recorded videos with discussions in virtual mode. All group works and engagements also moved into the virtual classroom using online tools Blackboard (BB) Collaborate and Zoom. Another key change in T2 2020 is all modes of students are treated as Cloud or online students and the teaching timetable was also made common for all students. The timetable was more flexible for Cloud students in the pre-COVID period. The academic staff of the respective unit was solely responsible to implement all changes in a very short time and became too busy to provide all updated learning resources. Therefore, direct student engagement time is reduced in T2 2020 which impacted on providing appropriate feedback on time. Lastly, as the student contact time was timetabled as common for all students, therefore normal Cloud students mostly missed the virtual lectures where they could discuss their issues and then relied on the recorded virtual sessions. Some of these changes affected some students and have no impact on some other students. The students' feedback response (questions in Figure 4) identifies these, as can be seen from Figure 6a. The student number (response rate) are 46 (37%), 60 (23.3%), 66 (45.5%) and 40 (32.5%) in 2018, 2019, 2020 and 2021 respectively. The questions Q4, Q5, Q7, and Q11 are related to assessment, feedback, quality teaching, and overall satisfaction respectively. Only 50% of students showed their agreement on receiving timely feedback in response to Q5 in 2020. In comparison to pre-COVID responses as shown in Figure 6a, these questions are heavily impacted, and all of these are directly related to the changes applied as mentioned earlier to adjust with the updated online mode of teaching.

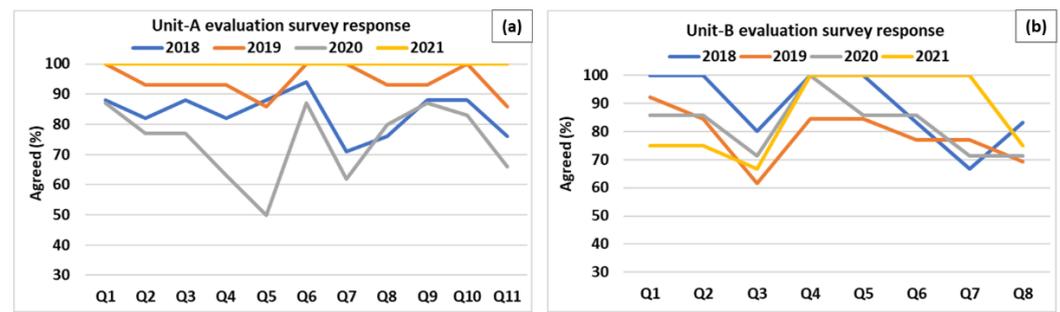


Figure 6. Unit survey response by students (a) Unit-A, Deakin university (b) Unit-B, Murdoch university.

The changed learning condition due to COVID-19 and long isolation or working from home impacted students' mental condition that influenced on welcoming the changed learning environment including changed learning assessments. However, with time students and staff became used to with the changed condition and with the implementation of vaccine eased the uncertainty and boosted the mental condition. Also, it was relatively easy for the academic staff to put more effort into student interactions (Q5 and Q3 in Figures 4 and 5 respectively) in 2021 as major changes were already done in 2020. Moreover, after addressing student feedback received in 2020 the quality of teaching and interaction time has been increased in 2021. This helped the students to become more understanding of the new learning approach, and this has been observed in student's unit evaluation feedback in 2021. Student satisfaction has been increased in 2021 and 100% agreed on quality feedback and overall satisfaction in 2021 as can be seen in Figure 6a. It is clear from Figure 6a that student found their confidence back and happy about all unit evaluation questions.

For Unit-B, in S2 2020, a hybrid/mixed mode has been followed where a weekly lecture was conducted in virtual mode using Blackboard Collaborate. However, workshops and Labs were conducted using both face-to-face (students who were in Perth during the offering) and online mode (students who were either overseas or interstate). From the student feedback (based on questions in Figure 5) response as shown in Figure 6b. The feedback questions are updated in 2020 and reduced to 6 questions compared to 8 questions during 2018–2019. Although the total number of questions was reduced but the question objectives remain the same which is highlighted in Figure 5. Therefore, student feedback responses are also presented here based on 8 questions for all four years 2018–2021, as shown in Figure 6b. The updated learning approach in 2020 was maintained in 2021 and both academics and students became familiar with the updated system and therefore the student's learning experience is as expected by the students. The student's unit evaluation feedback reflected this as shown in Figure 6b.

It is evident that students have not been affected severely due to updates or changes in the teaching and learning approach, and the feedback outcome in 2020–2021 is comparable to 2018 & 2019. The student number (response rate) are 26 (26.9%), 51 (25.5%), 47 (14.9%) and 26 (26.9%) in 2018, 2019, 2020 and 2021 respectively. From the detailed feedback, it is found that 72% and 100% of students were shown their agreement on receiving quality support from staff as a response to Q7 in 2020 and 2021 respectively, although feedback on marked assessments (Q3) and overall satisfaction on unit quality (Q8) rate remains almost similar like before. As mentioned earlier, academics were heavily involved with implementing all the required changes in learning resources, and hence, involvement with students either giving feedback or meeting or interaction was less in 2020 while communication and interaction (Q7) was increased in 2021.

In response to qualitative feedback questions like; "what are the most helpful aspect of the unit and what aspects of this unit might be improved?", the key words of students comments and suggestion are presented under three category (Most helpful, Not liked and how can be improved) as presented in Figure 7. It is clear that students did not

like the changed assessments and timing of assessments, long online session, workload although they mentioned about some good experiences too in 2020. Students also provided suggestions to improve the unit by ensuring more engagement with students, breakdown long session into small sessions, early feedback and more training on software tools used in the unit. Cloud students highly appreciated the way the lab experiments were recorded and suggested to keep the lab recordings even after on-campus activity resumes.

2018	2019	2020	2021
Most helpful Practical unit, Resources, practicals, plenty of study materials	Most helpful Clear assignments, intensive week, blackboard session, Seminars, practicals, group work, Interesting and challenging unit, feedback with good information	Most helpful Online practical is better for cloud students, lab quiz, software tool, quick response/feedback, organised course materials, lecturer approach, lecture slides and additional materials, seminars, lecture videos, good experience	Most helpful Lecturer knowledge, support, greater engagement, Practical videos, well organized, clear content, prompt answers/ feedback, lecture video, seminars, well-defined assessments
Not liked Tiring study, slow response/feedback	Not liked Older age student: group with younger student, self and peer assessment, too much content	Not liked Online quiz, insufficient quiz time, long seminars, seminar time, online sessions, too much work load, many assessments	Not liked Resolution of video quality
How can be improved More practicals, align practical with the study week, change test time, easy availability of software tool, more examples with software tool	How can be improved Addition guide for software tool, extra time for quiz, early feedback	How can be improved Practical video should continue when on-campus resumes, more engagement in seminars, include breaks to avoid boredom, early feedback, more training on software tool, include recent developments, effective planning	How can be improved More practical, high-resolution videos

Figure 7. Key attributes of students' feedback on qualitative questions.

Considering the student's feedback, with concerns, suggestions, and comments the assessment tasks were modified for an extended response window to suit diverse time zones, discussion time in the online session and dedicated more time on providing feedback on the individual query, which made the units more satisfied to the students in 2021, as can be seen in Figure 6a,b.

In summary, from the student unit evaluation feedback, it is evident that the applied approach in 2020 impacted student's overall learning though some students appreciated a few of the changes. As the necessary transition of learning resources is reasonably completed in 2020 and with careful adjustment based on student's feedback on unit evaluation in 2020 the delivery of the units in 2021 is found more acceptable to the students. The key attributes for better learning environment that helped in 2021 are ensuring greater interactions, informative feedback, flexible timetable, appropriate assessment, quality video recordings and organized resources. Therefore, a right plan to implement these will made the online and mixed/hybrid mode of delivery successful in future as well.

5. Globally Observed COVID-19 Challenges on Education

COVID-19 has a profound global impact on people's lives and health. As of 28 February 2022, over 438 million confirmed cases and 5.96 million deaths were reported globally due to this [20]. To minimize the spread of this highly contagious virus health experts and World Health Organisation (WHO) suggested implementing isolation. The lockdown, social distancing, and closure of educational institutes are observed in all countries which almost paralysed the education system. This leads to a paradigm shift of face-to-face teaching and learning to the available other alternatives such as online mode [21]. Students and teachers were compelled to adopt mostly the online system for which all were not well prepared. This shift is not easy, all countries experienced different types of challenges in it and many countries found it very challenging.

Authors [22] mentioned that COVID-19 related isolation introduced challenges in engineering education in Moscow, Russia. The authors questioned the legal perspective of distance learning and also questioned the efficiency of distance classes. Authors in [23] sates that problem of online education is relevant to the urgent transfer to online mode during

pandemic, however it provides opportunities to update teaching mode, learning contents, teaching concept, teaching level and assessment means and provides scope to employ new tools for engineering education. Authors in [24] proposed ideas to solve the difficulties of conducting experiments during pandemic by using specialized technology such as; virtual reality (VR) and augmented reality (AR), however they raised concerns about lacking of strong ethical guidelines for this. Researcher in [21] discussed about challenges of running virtual/augmented/extended reality (VR/AR/XR) lab for research and education maintaining strict restrictions and hygiene rules. They also mentioned that classes, seminars can be moved to online mode however researchers can take equipment's to home (when possible) while colleagues can provide remote support to conduct the experiments. Authors in [10] analysed the benefits and proposed the use of augmented reality (AR) in online delivery of power engineering education during pandemic. However, authors in [25] highlighted some key challenges such as the unavailability of internet service, and limited resources accessibility during the COVID-19 outbreak, which is also experienced by many students in Brazil [26]. Authors highlighted that there is a lack of policy guidelines for online delivery of engineering courses and assessment techniques for quality teaching. The authors also highlighted the challenges to ensure engagement. Although psychometric study on applied computing course students found that online flipped classroom and remote assessment is suitable for the course and for student performances [27]. Authors in [28] indicated that schools, colleges, and universities have discontinued face-to-face teaching during pandemic in Bhutan. The shortcomings of effective transitioning to an online approach include infrastructure problems, limited exposure of teachers to online teaching, information gap and unfavorable home environment made it challenging to maintain academic excellence in higher education in Bhutan. Also, vulnerable, or weak students face difficulties in having effective supervision and guidance. Although active collaboration has increased among teaching staff to understand and improve online teaching methods. Collaboration is the key for group work which integrates high level of characteristics among collaborators by focusing on common tasks and working environment. Authors [29] analysed different dimensions of work with augmented reality to develop conceptual framework and proposed human-centered taxonomy to characterize and evaluate the collaboration process in group work. Authors in [30], stated that Philippines opted for online teaching in April 2020 without any coordinated approach as universities were not prepared for it. Some teachers prepared recorded videos and used Google Classroom, WebQuest but a majority of the teaching staff were not prepared for online education. It is also found that [31] students are happy with distance education model as that helps them to avoid academic disruption during the pandemic. Authors in [32] evaluated student's perception of using social media as an academic learning platform, collaboration, and engagement platform under confinement conditions and found its positive impact on academic performance. Authors in [33] mentioned that engineering education in the U.S. is redesigned for a remote learning environment. The forcibly transitioned engineering education from in-person mode to a remote-learning environment in a short time put challenges to instructors and students. The transition was difficult due to a lack of resources for instructors and students, and unfamiliarity with the new approach. Also, labs are challenging, and it is a curriculum requirement by the accreditation board. Due to lack of preparedness, unfamiliar learning environment, and lack of interactions, students expressed dissatisfaction and faced challenges to stay motivated, which made their learning more difficult. However, authors in [34] states that applying innovative teaching method can address the challenges of distance/online learning environment and improve student performance under special learning environment due to pandemic. Again, authors in [35] examined the sustainability landscape in higher education during the COVID-19 pandemic and critical effects on university practices highlighted such as; unpreparedness for online delivery, difficulty in access to digital technology, and limited access to reliable internet. Authors also indicated that these effects mostly affected the low socioeconomic and vulnerable students which challenges to maintain Sustainable Development Goals 4. Therefore it is suggested to

focus our effort on the sustainable development in higher education domain. Moreover, seven evidence-based steps are presented in [6] on how engineering students can thrive for outcome based education (OBE) settings in these challenging times.

Apart from the individually identified challenges highlighted above, a uniform survey was conducted by UNESCO [9] to assess the impact of the COVID-19 pandemic on higher education. Responses received from high-income countries and the Europe and North America regions are summarised below.

- The increase in online teaching is the major impact. The hybrid teaching mode was found more popular.
- Student enrolment is impacted although varied by region and income level. International travel restrictions impacted enrolment, but domestic enrolment increased.
- International students are affected even more than local disadvantaged groups.
- Despite university campus closure, most countries reported that academic and administrative staff employment and salaries were not impacted. Although some countries reported the opposite and private sector was impacted in delay or cut in salaries.
- Due to campus closures, many research activities have been suspended or delayed, or even terminated. Although an increase in research activity was observed in the medicine and relevant field.
- Observed reduction in maintenance and service work in on-campus, although increased expenses to expand the online infrastructure.
- The most concerning impact assessed by governments are students' disruption of study or research or campus activity flowed by finance and physical and mental health.
- COVID-19 significantly reduced job opportunities which impacted transitioning tertiary level students to secure jobs.
- The national priority of various countries is to improve the infrastructure and availability of digital devices, teacher training, guideline, and tools for online and distance learning.

Therefore, COVID-19 has challenged the teaching and learning system in many ways in most of the countries as well as in Australia. Compared to any other country, Australia is different due to its geographical location, economic and social condition, government commitment, and the way the states and the country operate. Australia is a more privileged country than many others, however, the education system still faced significant challenges during COVID-19. Table 1 summarises the key challenges observed in different countries and identifies possible actions to manage the challenges for the teaching and learning progress.

Table 1. Challenges and Opportunities Observed in Different Countries.

Focus Area, Country, [Reference]	COVID-19 Challenges	Actions Taken/Suggested
Stress among University students, China [36]	Online learning may elevate mental distress and depression symptoms (due to factors like; isolation, social distancing, and discrimination).	Necessary intervention is required to modify the factors to reduce distress and depression.
Remote Engineering Education, USA [33]	Transitioning to remote learning in a very short time puts challenges to instructors and students. Lab-based courses are a real challenge Lack of face-to-face interaction developed negative emotions and anxiety among students	Providing a positive learning experience to students
Engineering Education, Moscow, Russia [22]	Engineering education is forced to change as fast as ever before. Operating hardware or lab-based work was not possible.	Adopts legal norms, getting familiar with the novel means, improve the workplace to improve learning outcomes. Implementation of digital twin concept.

Table 1. Cont.

Focus Area, Country, [Reference]	COVID-19 Challenges	Actions Taken/Suggested
Engineering Education, Pakistan [25]	Engineering education impacted to implement of the theory in lab work Transforming all face-to-face learning activities to online mode. Adapting to online mode is challenging for academics and students	Designing course targeting for online teaching The virtual classroom can create an environment for interaction University should provide the necessary infrastructure, training, and policy guideline for standards of online teaching
Education system, Bhutan [28]	Accessibility to the internet and online resources Affordability of online resources Lack of supervision or guidance Authentic assessment and timely feedback Suitable place for online study	Online teaching or classroom Recorded video Proper training is required for teaching staff The right policy is required for online infrastructure and staff development for effective pedagogy
Higher education, Philippines [30]	University and teaching staff are not prepared for online learning	Strengthening the educational planning and health measures in universities can provide an opportunity to continue online learning
E-learning for international students, Australia [11]	E-learners/online students are likely to feel isolated, disconnected, and emotional instability in the online/virtual learning environment. The satisfaction level of e-learning and e-practice can affect the learning experience/sociocultural conflict of international students in Australia.	Increase conversation with online and international students to maintain quality education under the online method. Further research is required to evaluate the online learning and practice and design online courses considering the special needs of international students (for situations like COVID-19 lockdown).
Factors of e-learning satisfaction, Malaysia [37]	Student's willingness to online study is facilitated by online learning stress, IT facility, skill, and cost which also dictate online learning satisfaction.	Development of efficient and effective IT guidelines. Providing adequate training on online learning and enhancing learning management systems.
Sustainability of the online education system, Spain [38]	Students were not prepared and found online courses difficult to follow. They felt that their academic performance lowered, moreover households required additional funding for home ICT equipment, which was not an affordable option for all	Higher education institutions must ensure inclusive, equitable, and quality education with sustainable activities.
Academic Training, Spain [14]	Academic training demand increased for online teaching, digital tools, online assessment and design of online courses. The key challenges observed are lack of time for adapting and complexity of online evaluation.	Facilitate continuous training program and developing collaboration among academics for improvement of online teaching.
Higher education institutions, EU27 [39]	Lack of pedagogical knowledge to transform from traditional mode to distance mode dependence on teaching platforms, technology, and the relationship between student, teacher, and other staffs.	Change or update pedagogical strategy and rethink the processes and adapt with the new normal condition.
Student's role in online engineering education, Global [6]	Biggest challenge is to figure out an effective way of completing lab work in online mode. The shift to digital or online learning is creating a new form of social division, particularly for disadvantaged and less-privileged students. Changes in education method on an ad-hoc basis creates more inequality.	Virtual labs, and simulations can serve the pedagogical needs although they cannot be a replacement of hands-on experience with real devices. Extra attention is required to maintain access to facilities such as the library. University and government can develop a policy for the education system during and beyond COVID-19.

6. Findings and Recommendations

As of today, it is very difficult to predict when the COVID-19 pandemic, its risk, or related restrictions will come to a complete end. The higher education sector, in particular engineering education, is facing enormous difficulties to battle this pandemic situation. Hence, it is urgent to bring a suitable and effective teaching and learning approach to engineering education involving all the stakeholders, governments, policymakers, the higher education sector, academics, and the students. Based on the lessons learned from the available literature and students' feedback from the two studied engineering units in Australia, this study presented a few recommendations that can be considered for improvement of the teaching and learning approach in the future delivery of any online, virtual or hybrid offering.

Observation-1: Online or remote or cloud learning is highly dependent on support infrastructure, software tools, and internet bandwidth, and accessibility.

Recommendation: A holistic national approach can be taken to improve the capacity building of all universities as well as infrastructure building at the national level.

Observation-2: Academic staff, students, and parents all are confused to some level about the effectiveness of online teaching. Also, not all staff and students are prepared and familiar with the available tools for online teaching.

Recommendation: Necessary training for staff development can be more effective, which can eventually translate the effectiveness of online tools to students.

Observation-3: The unit structure, resources, assessments, and learning objectives are not clearly defined at the current stage that best suits the online teaching method.

Recommendation: Act on innovative teaching or update the relevant policy at the course/discipline or university level to clearly define learning activity and assessments that meet the quality and accreditation needs.

Observation-4: Lack of engagement develops anxiety and stress among students and that can impact on student performance.

Recommendation: The effective virtual classroom, timely feedback, and flexible timetable for different student groups can keep all students engaged. More interaction among students and academics can be created with group activity which can improve engagement.

Observation-5: The major challenges observed is the hands-on work or lab experiments, which is a key learning requirement for engineering students as well as important for accreditation.

Recommendation: Mixed/blended mode of delivery can be the best option where either recorded lab videos with all guides and results can be shared online and in preferable time complete the lab on campus in an intensive way. The other option can be translating it into a suitable simulation lab or developing labs using virtual reality (VR).

Observation-6: There is a lack of uniformity in the online mode across universities and different ad-hoc approaches are currently in place. This will impact the learning quality in long run.

Recommendation: A uniform and national/international guideline should be included in education policy which should be consulted for a global standard to practice.

The COVID-19 and its numerous new variants indicated that the fight is not coming to an end soon and similarly the restrictions, lockdowns and taking precautions will be part of our life in the coming years. Therefore, necessary actions should be taken by universities to adopt or update the policy and standard for campus, online and mixed/blended mode of teaching.

7. Conclusions

Online teaching and learning are successful in practice in selected courses in different forms. The potential of online learning has been extensively tested during this lockdown and isolation period across the globe although the best practices and globally accepted online teaching in engineering education are yet to be determined. This paper identified and explained some challenges faced by students and teachers in different countries. It

also compared the COVID-19 impact in two different states in Australia where lockdown and restrictions were different. The findings indicated that sudden transition to online education was the key challenge for academics and students in many countries. Moreover, infrastructure for online education was not adequate for many universities and it was beyond the capacity for many students. Similarly, the lack of knowledge on online tools was another barrier for academics and students. In addition, the significant transformation was required in study resources and updating in teaching philosophy and attitude. Moreover, studying from remote locations without appropriate interaction and collaboration impacts on students' performance and which eventually developed stress on students. On the other hand, academic staffs also felt stress on how to transfer different learning attributes effectively to students and how to assess the students' performance. The two different unit performance assessment in two different settings in two states in Australia shows that in 2020 or during the transition to completely online and/or hybrid mode students were not happy in many aspects such as assessment, online seminar, timing of online seminar, workload and lack of interactions, however when appropriate actions taken to address these in 2021, students found the online and/or hybrid mode of learning experience is satisfactory to achieve their learning goals. To enable the better learning experience academics played key role to ensure greater engagement and support for students with updated learning resources that are easily accessible to the students with clear and informative feedback. Moreover, updated teaching and learning philosophy and learning practice over two-year period has set a new expectation and goal on students' mindset which helped to welcome the online learning approach beyond the COVID-19 pandemic period. Similar experiences observed in many other countries, and they took various measures to address the challenges initially in an unplanned or ad-hoc way. The infrastructure and technological limitation are found one of the major challenges that is a national issue to resolve by government initiatives. The curriculum design is institutional responsibility and developing innovative curriculum with updated learning resources are the academic staff's responsibility. Staff development to adopt with the technology and developing appropriate skillset is also institutional responsibility with the willingness of the academic staff. Moreover, affordability of the new technology depends on financial capacity and for the sake of nation building respective government should make it affordable and accessible for all students. Therefore, a global holistic approach and policy should be adopted by addressing all the recommendations outlined in this paper to make online teaching and learning more sustainable and acceptable to engineering student.

Limitations and plan of future investigation

This study was conducted within a restricted timeframe with only two units from two universities, also the use of data was permitted for limited use. Moreover, this study compared the pre-COVID and during COVID situation, therefore post-COVID knowledge would be helpful for establishing a stronger relationship. However, these does not invalidate the findings as several study by other researchers from different countries as summarized from various literatures reflect the similar findings. This study will be further extended in collaboration with several other universities to compare the pre-COVID, during COVID and post-COVID T & L experience to establish stronger evidence for identifying the most critical challenges for better education in future.

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