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Pandemic-induced course and assessment changes for undergraduate engineering education: The Development of Graduate Attributes

Toh Yen Pang
RMIT University, Australia, tohyen.pang@rmit.edu.au

Alex Kootsookos
RMIT University, Australia, alex.kootsookos@rmit.edu.au

Elena Pirogova
RMIT University, Australia, elena.pirogova@rmit.edu.au

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Pandemic-induced course and assessment changes for undergraduate engineering education: The Development of Graduate Attributes

Abstract

Educators constantly need to make adjustments to their pedagogy and learning activities to reflect the fast changes in society, the economy and industry. This has been clearly demonstrated throughout the world in the response to the COVID-19 pandemic required fully remote delivery of tertiary education. The aim of this study was comparing the experiences and perceptions of tertiary students in a fully online and a blended delivery mode, particularly in response to their laboratory skills and development of graduate attributes. Pedagogical aspects were kept consistent across delivery modes to minimise the differences in learning activities across cohorts. A comparison was made between the 2020 fully online cohort and the 2021 blended delivery cohort. The students were asked about their perceptions of how well they thought the course developed their graduate attributes; how authentic they thought the course was; and how easy the content was to navigate and understand. A mixed methods approach was used, where both quantitative and qualitative data was gathered. The blended delivery mode students appeared to benefit from having a specific reflective task, which allowed them to see their learning in a broader context. The paper discusses the blending and online learning from the students' perspectives of developing graduate attributes and experiential learning. Specifically, where hands on skills are required, students need further guidance in "learning how to learn" or metacognition. A key challenge for future blended learning is getting the balance right between achieving efficiency in online learning and lack of social and dynamic interactions aspect of the online community.

Practitioner Notes

1. This study focused on strengthening the blended learning for students to undertaking engineering education at university level.
2. The findings also examined pedagogy and the used of technology in blended learning environment.
3. It is important to recognise blended learning is not just about the educational tasks at hand, but also maximising the social relationship among students as they work collaboratively on the learning tasks.
4. Successful blended learning requires achieving a balance between the technical efficiency in online learning and the social capital gained in face-to-face learning.
5. A key challenge in any blended and online learning environment is the importance of supporting students' psychological well-being.

Keywords

tertiary education, engineering, blended delivery and learning, graduate attributes

Introduction

Conventional face-to-face presentations, in-class group activities, traditional laboratory experiments and paper-based assessments have been the foundation of university classroom teaching for many decades. The recent advancement in, and the ready accessibility of, a full range of communication and online technologies, especially in the current context of the global SARS-CoV-2 pandemic, have changed the way educators teach students (Ibrahim & Nat, 2019; Snart, 2010; Zhao & Song, 2021). Due to the highly dynamic and infectious nature of the coronavirus, hundreds of millions of people around the world have lived through lockdowns that forced them to study and work from home to combat the pandemic. These have resulted in serious interruptions in many institutions, including schools, colleges and universities, where educators have been forced to transfer their standard hands-on and face-to-face teaching approaches to online equivalents. A hybrid model of work for the foreseeable future has already emerged, for which our students must be prepared. As educators, we had to reconsider the way we interacted with students and how students were to be assessed (Pang et. al., 2020). Hybrid learning approaches, with an effective integration of traditional classroom teaching and newer communications and online technologies, have allowed students to continue to pursue their learning opportunities (Singh et al., 2021).

Many authors have suggested the terms ‘hybrid’ and ‘blended’ learning can be used interchangeably to encompass this accelerated shift to online learning (O'Byrne & Pytash, 2015; Siegelman, 2019; Singh et al., 2021). However, there is a difference as online components of hybrid courses are intended to complement in-person class time. Having said that, the goal of both blended and hybrid learning is to provide opportunities for students to engage with their instructors and the course content. According to Garrison and Vaughan (2011), blended and hybrid learning asks educators to rethink the way they might transform teaching and learning in light of the possibilities that new technology offers, so that educators can engage with students in the virtual online environment variously through discussions, breakout sessions for group work, lectures and other activities (Smith et al., 2018). As pointed out by Smith et al. (2018), it is important teaching staff have regular check-ins with students, either in person, online or via-email, to address any questions and concern they may have in their knowledge and in the course and content area. Accordingly, it is imperative that blended and hybrid learning approaches include options for both synchronous and asynchronous learning to supplement face-to-face classroom teaching and learning (O'Byrne & Pytash, 2015; Smith et al., 2018; Xiao et al., 2020; Yuen, 2011). Synchronous communication was found to be more interactive and dynamic in allowing for students to meet with teaching staff online to receive feedback and advice with problems; whereas, asynchronous communication worked well when students learnt at their own pace and time or when they were in different time zones.

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Technology provides a transformative incentive for developing diverse methods in educators' pedagogical practice in blended and hybrid learning. Just how technology is being used to support blended and hybrid learning and how the technology interacts or integrates with the learning process are of great interested to researchers (Bernard et al., 2014; Marie & Shannon, 2015; Olapiriyakul & Scher, 2006). According to Olapiriyakul and Scher (2006), the technologies that support hybrid (and blended) learning can be divided into: (i) technology infrastructure; (ii) instruction technology; and (iii) technology that supports the learning process or activities. When re-designing and re-developing a course to be delivered through a hybrid or blended mode, it is important to consider the content, in the context of students' learning styles and taking responsibility for their learning pace, time, place and circumstances, as well as the appropriate use of technologies in order to equip them with knowledge acquisition by noting: (i) the amount of scaffolding needed to support learning; (ii) the design of the learning materials that students consider useful; and (iii) the medium of Information and Communication Technologies (ICT) and Learning Management Systems (LMS) applications to engage with their learning and information (Bennett et al., 2020; Marie & Shannon, 2015; Olapiriyakul & Scher, 2006).

O'Byrne and Pytash (2015) have argued that simply using technology in instruction does not ensure students will be motivated or engaged, and improvement in their learning outcomes is not guaranteed. Indeed, there have been many studies investigating students' motivation and engagement in online learning (Al-Qahtani & Higgins, 2013; Jayalath & Esichaikul, 2020; Koh & Lee, 2017; Lee et al., 2019; Lo et al., 2021; Priego & Peralta, 2013; Xiao et al., 2020). The results of these studies were mixed depending on the nature and the balance of online and face-to-face components. For example, in one case study, Lo et al. (2021) compared traditional teaching methods with flexible learning in a multicomponent, blended learning mode in an undergraduate chemistry course. The results showed that students' engagement and motivation were enhanced in the flexible and blended learning mode because they could study and digest the knowledge at their own pace. However, other studies have found that, due to isolation and lack of social interaction and communication in fully online courses, students were significantly more likely to withdraw or not complete their courses compared with their traditional learning counterparts (Al-Qahtani & Higgins, 2013; Wang et al., 2019; Xiao et al., 2020). Several researchers (Lim et al. 2019; Lo et al. 2021) have suggested practical instructional activities that enhance students' sense of engagement during online or blended learning, including: (i) asking short questions; (ii) providing timely feedback; and (iii) using pre-learning video clips for more complex content.

In terms of students' learning competences and satisfaction in hybrid and blended learning spaces, many educators have implemented innovative ways to enhance students' experiences (Deveci Topal, 2016; Harahap et al., 2019; Ilgaz & Gülbahar, 2015; Lim et al., 2019; Linda & Terri, 2014; Xiao et al., 2020). Drawing on Dada (2006), Xiao et al. (2020, p. 1207) argued that "Learning competences can be defined as skills and knowledge that enable learners to be ready, eager and prepared to make benefit of a learning experiences". The Economist's Intelligence Unit has argued that, globally, education systems are not providing sufficient training in transferable skills, which students must acquire to be ready for the workforce. To date, very little progress has been made in incorporating employability skills into the classroom, particularly as these skills are linked to everchanging technology (Kenworthy & Kielstra, 2015). The top three essential employability

skills in common in the commentary are problem-solving, teamwork, and communication (Fajaryati et al., 2020; Mishra & Mishra, 2018; Kenworthy & Kielstra, 2015).

While these studies focus on learning competences, they neglect to include discussions of pedagogical practice and, more importantly, the interaction between learning competences and pedagogical practice. Bennett et al. (2020, p. 1191) argues, “The space relates directly to mode/s of teaching and the two interact to produce a common goal of transformational engagement. This relates not only to learners’ engagement in information processing but to their critical thinking and problem-solving”. The key problem of enhancing employability skills in a hybrid or blended learning space, however, has yet to be investigated.

The study we are reporting here sought to assess the interaction between learning competences and pedagogical practice. Therefore, the purpose of this paper was to outline students' experiences of, and attitudes toward, blended learning delivery and to determine whether the interaction of pedagogy and technology was instrumental in improving learning outcomes. We describe the shifts and changes in this interaction in Pang et. al. (2020), which reported on an online learning mode only. Then, we compared the earlier online-only learning mode with a blended model to assess the students’ perceptions and experiences. We also undertook a survey of students’ responses to blended learning in an undergraduate Biomedical Engineering course in 2021. The survey aimed to answer the following research questions:

1. What are the students' experiences of, and attitudes toward, blended learning in terms of pedagogy and the technological aspects of the course?
2. What are the students’ experiences of, and attitudes toward, the face-to-face and online components of blended learning?
3. What are the students' reflections on the blended learning approach in relation to developing their employability skills?

Methods

Biomechanics course in a blended learning mode

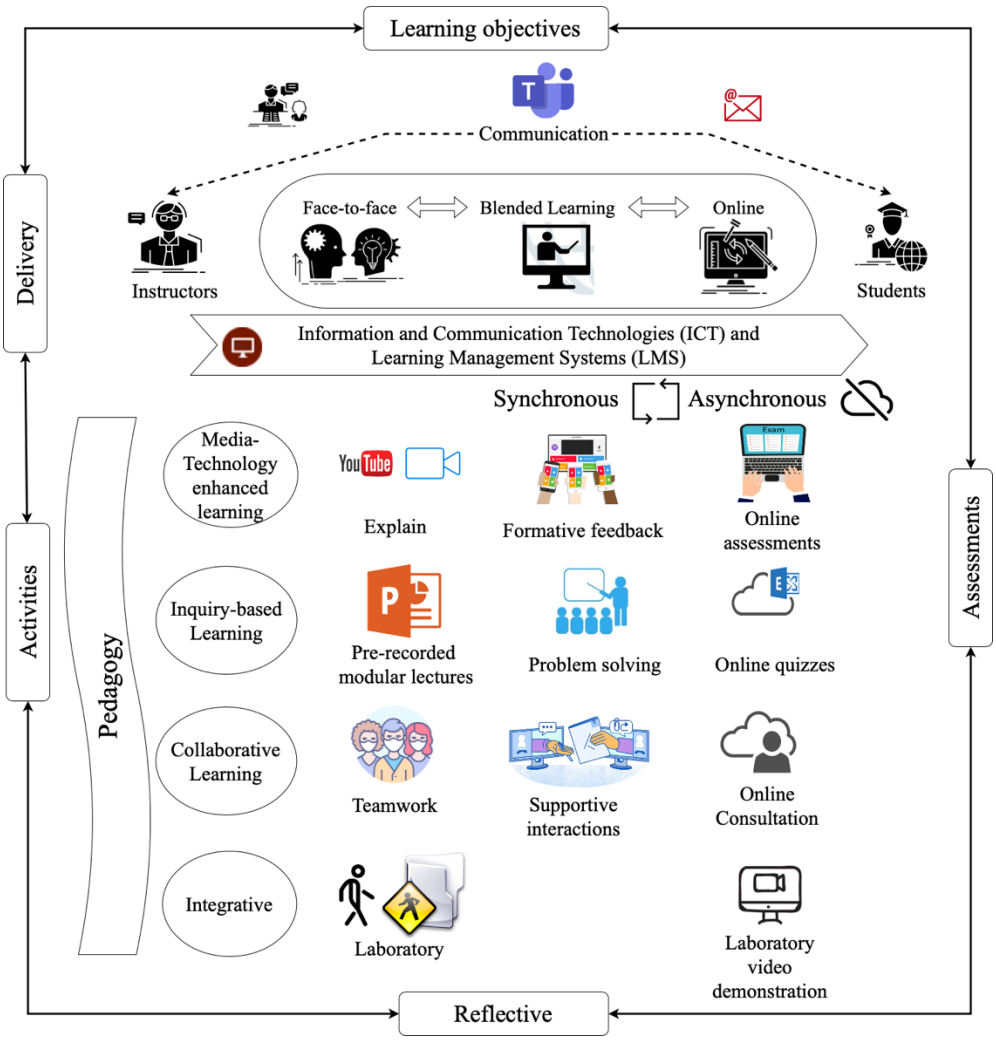
Figure 1 summarises the pedagogical model and the teaching and learning delivery methods used in the course in this study. Specific learning objectives were clearly stated in the course outline. Upon the completion of the course, students would be able to: (1) understand key biomechanics concepts; (2) apply these concepts to solve real-world problems; and (3) apply systematic approaches to the conduct and management of engineering projects. The course included two individual assessments and one group assessment to evaluate students’ performance. Feedback was provided to guide their ongoing learning. This course included a variety of learning activities and delivery modes to enhance the students’ learning.

The SARS-CoV-2 pandemic is far from over, and as a result the RMIT University developed guidelines to maximise the amount of campus time for students whilst also providing a COVID-safe campus environment. To ensure all staff and students were (and are) compliant with COVID-safe physical distancing measures, only 50% of learning and teaching activities for Semester 1, 2021 were delivered on campus. All lecture materials were pre-recorded and made available on the LMS (in this case ‘Canvas’) to support dissemination of information on lessons and

assignments to students. We also used media technology, such as YouTube and Screencast-O-matic, and game-based learning platform, i.e. Kahoot, to support learning activities and enhance teaching–learning interactions. Information and Communication Technologies (ICT) have been an integral part of these teaching and learning activities to foster interaction between students and teaching staff. The blended learning activities combined various synchronous elements (face-to-face and video-conference meetings) with various asynchronous elements (pre-recorded lectures, assignments, online quizzes, research, and collaboration).

Figure 1

A general framework to support blended learning approach for Biomechanics course with lectures, tutorials and laboratory activities



The course integrated three different pedagogical models: inquiry-based, collaborative, and integrative and reflective learning (Sotiriou et al., 2020). In the inquiry-based model phase, students were encouraged to engage in problem-solving and discussion in structured activities and questions relating to concepts learned in the pre-recorded lectures. The teaching staff supported them with explanations and formative feedback. In the collaborative learning model, students were asked to work in small groups and conduct problem-solving in the form of the

hypothetico-deductive method of reasoning (Ju & Choi, 2017). The learning activities encouraged students to analyse problems, formulate research questions, design experiments, understand analysis, interpret results, search for explanations and improve their comprehension of biomechanical problems. The integrative and reflective learning model was adopted to help students make connections between theoretical knowledge and practical skills so that these skills could be applied to solve complex and challenging real-world problems.

In the previous, fully online version of the course delivered in 2020, a specific group project was devised for students to explore the extent to which the salient sounds can influence body movement, targeting individuals suffering from disorders of motor control degradation, reported in Pang et. al. (2020) As students were not able to attend face-to-face laboratory sessions, they were asked to watch videos on conducting home-based human motion analysis. Students were asked to conduct risk assessments to ensure their safety and the safety of participants before starting to conduct the same experiments at home with one or more members of their households to learn the technique of measurement. They were also advised to use their personal devices and open-source software (in this case, 'Kinovea') to conduct their home-based experiments and to interact with peers and the course coordinator online to keep them stimulated and engaged. During the online activities, the instructor met the students via 'Collaborate Ultra', a real-time video conferencing tool that allows users to share files and applications and use a virtual whiteboard to interact. Collaborate Ultra also allows the online sessions to be recorded, so students both could catch up on missed sessions and review the content at any time.

In 2021, the face-to-face teaching mode in this course included lectorial and laboratory sessions. Laboratory sessions that were timetabled on campus had to have an online equivalent for students unable to attend campus. For the blended learning, the group task was adapted to allow students to undertake the tasks either at home or in the campus laboratory. Laboratory sessions were conducted in smaller groups, during which students had the opportunity to learn and use the Vicon System© and Nixon™ software for movement analysis to carry out their experiments in a controlled environment.

For 2020 and 2021, the individual assessments were online tests utilising multiple-choice, short-answer and problem-solving questions to measure students' ability to relate and apply biomechanics concepts to biomechanical problems. The online assessments were made available on Canvas for at least 24 hours and students had the flexibility to undertake the assessments at anytime and anywhere, so long as they had access to an internet connection and could log-on to Canvas. Once they logged-on, they needed to complete and submit the assessment within two hours. As part of the course assessments, all students were also required to prepare a group and/or individual reflective statement.

Participants

Participants in the study were students enrolled in the Biomechanics course, which is a core course in the four-year Bachelor of Biomedical Engineering (Honours) degree.

Research design, data collection and analysis

In this section, we are reporting on two data points, i.e. students in the 2020 and 2021 cohorts (see Table 1). They were also invited to respond to the online course experience surveys at the end of the semester in both years. This study was designed as a mixed-method study in which qualitative and quantitative methods were employed. The data were collected, first, through the online course experience survey, which was designed with questions framed as a 5-point Likert-type scale, coded from 1 = 'strongly disagree', 3 = 'neutral', and 5 = 'strongly agree'. This was used to assess the students' satisfaction for each item. At the end of the survey, two open-ended questions were included for students to provide their opinions on the course. (A sample of survey questions used in this study is included in Appendix A.) These were included in the qualitative analysis. Finally, a written, group and/or individual, reflective statement had to be provided by the students detailing their teaching and learning experiences, team processes and skills development. Guidelines on writing reflective statements can be found in Pang et al. 2022.

Table 1

Number of students enrolled in the Biomechanics course in 2020 and 2021 by gender, age group and background.

Cohorts	2020		2021	
Age Group (years)	N	%	N	%
<21	2	9.1	7	13.7
21-24	19	86.4	38	74.5
25-34	1	4.5	6	11.8
Gender				
Male	13	59.1	30	58.8
Female	9	40.9	21	41.2
Background				
Australian	20	90.9	41	80.4
International	2	9.1	10	19.6

In 2021, additional specific questions were included in the online survey to gather the information on the students' attitudes toward the materials used in the course, the online learning tools, instructor-student interaction and employability skills. They included, for example: 'The web-based (online) materials for this course are effective in assisting my learning', 'I like being able to do most of the work online for this course', 'I learnt a lot through the process of drafting and resubmitting my assignments', 'The course helped me develop my ability to work as a team member'. Quantitative data from the online survey were presented as percentage in bar charts.

For the qualitative analysis, content analysis was conducted on responses to the two open-ended questions and the reflective statements, and an inductive coding technique was applied (Corbin & Strauss, 1990; Vogt et al., 2014). This coding process comprised three steps: (i) open coding, in which first author read through the qualitative data and identified distinct themes for categorization; (ii) axial coding, in which the first author reread the data to identify emergent categories and sub-categories to draw connections between codes; and (iii) selective coding, which involved the integration of the categories that had been developed to form the initial theoretical framework. The data were analysed via these themes.

Results

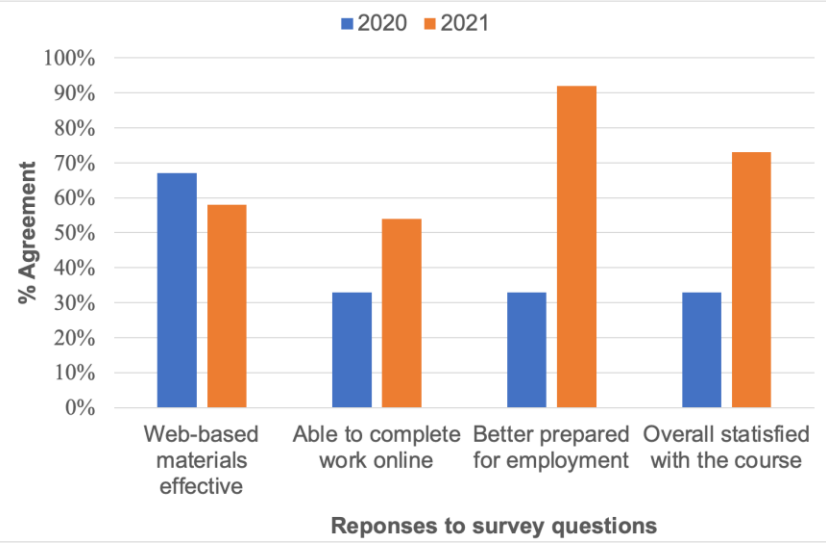
The 2020 and 2021 online surveys provided the dataset for the cohort comparison. A total of 3 and 26 students responded to the online survey in 2020 and 2021, respectively.

Cohort comparison about the course

For this cohort comparison, data were drawn from the same course for the 2020 cohort that experienced fully online delivery and the 2021 cohort that experienced the blended learning model. Figure 2 shows the percentage of student who responded to the online survey on the materials used, online tools, and employability skills development and overall satisfaction for the course. The survey found that 58% of students in 2021 'agree' that they found the online materials effective in assisting their learning. The number was slightly lower than the previous year. When asked if students were able to conduct most of their work online, 58% of students agreed, which was higher than the year before. When comparing the previous, fully online version of the course in 2020 with the blended mode in 2021, the majority of the students in 2021 agreed that the course had better prepared them for employment, and overall student satisfaction was improved, from 33% to 73%.

Figure 2

Students' attitude toward the materials used and communication tools, employability skills and overall satisfaction in relation to the course

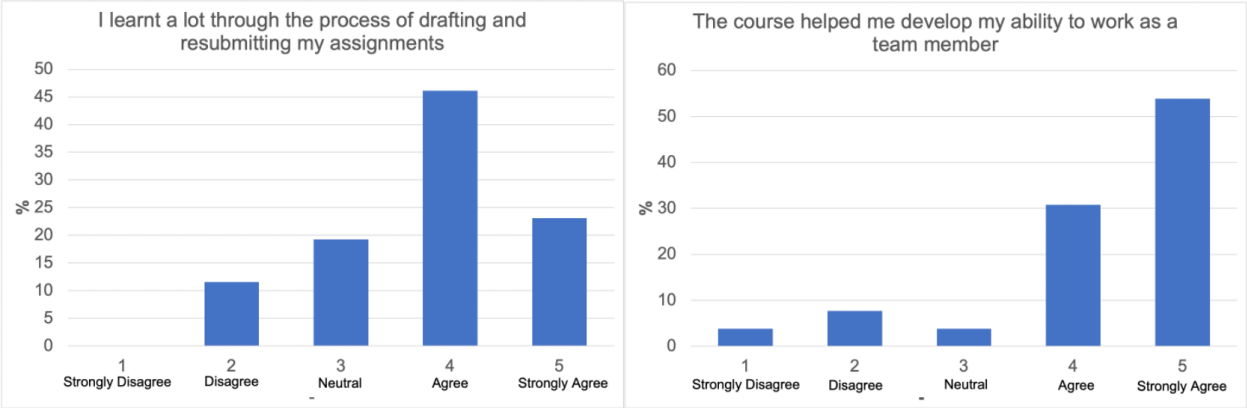


Blended learning and delivery aspects of the course

Here we report on one data point in 2021. When the survey questions relating to blended learning were considered, 69% of students indicated that the instructor-student consultation sessions, which helped them to develop research objectives, formulate research questions and receive feedback on their draft proposals, were helpful. A larger number of students (85%) agreed or strongly agreed that this course helped them to develop their ability to work as effective team members (Figure 3).

Figure 3

Students' attitude toward instructor-student interaction and their ability to work effectively as a team member in relation to the blended learning (2021 cohort)



Two themes were explored from the students' reported experiences of, and attitudes toward, blended learning in terms of the pedagogical aspects of the course. These were: (i) course organisation and delivery; and (ii) collaborative project-based learning. In relation to the first theme, course organisation and delivery, students indicated the integration of practical real-life examples into the online quizzes helped them in grasping key biomechanics concepts better:

> *Liked how we got to have a go at using the Vicon system. Using real-life examples in sport during the lectures to help me understand the concepts. Liked how we go through practice example questions in class.*

Furthermore, students also enjoyed the integration of gamification with complex concepts that enhanced their learning and engagement. One student stated:

> *I really like the way the lectures were delivered at the start of the semester with the Kahoots encompassing the whole lecture and the expectation that we study the content before the lecture. I really felt that having the practice quizzes and doing questions helped me learn a lot.*

However, the negative responses focused on the format of the pre-recorded lectures. Students disliked the PowerPoint format and reported that they would prefer video lectures accompanied by slides to follow:

> *Pre-recorded lectures, I didn't like the PowerPoint style lectures. I prefer the uploaded lectures we can watch on Canvas, with the slides being a separate pdf.*

In relation to the second theme, project-based learning, students indicated they liked actively collaborating with each other to engage with real problems and interact with industry standard technology to acquire deeper knowledge:

> *Working as a team, interacting in gathering results, being exposed to valuable technology that could be useful further in my studies.*

Hands-on aspects of the course

Here we report on two data sets based on the qualitative data in 2020 and 2021. Students in 2021 were given option to conduct the group project either (i) in the laboratory (using the Vicon system (motion capture technology)) and analyse their results using the Nexus software, or (ii) remotely (using their personal smart devices with a camera) and analyse the results using an open-source software. The responses to these options were varied. In relation to the experiment being conducted in the laboratory, most students found that they needed to spend a lot of time learning how to calibrate and operate the motion-capture technology and its associated algorithm to obtain reliable data for movement analysis. Some of the students commented:

> *I was able to have physical labs on collecting and analysis data. I also got to learn in depth on how to analyse data and how write a proper research paper.*
>
> *Working with the Vicon system, though frustrating, was rather interesting to see all the biomechanics of a walking gait.*
>
> *The Vicon system itself needs improvement. It was very time consuming trying to calibrate the system and do the analysis. I'm not sure if this was just the method we were using or the equipment, but there wasn't anyone experienced enough with the system around to help us out.*

When compared with the online-only model in 2020, and despite students managing to have a standardised procedure to conduct gait analysis remotely, they found the experimental set-up at individual homes and personal devices with different camera resolutions may have altered the accuracy and reliability of the data collected. One student group stated:

> *… because of the social distancing requirements caused by the COVID-19 pandemic, the experiment had to be performed at home. Although a standardised procedure was followed, some variables could not be made the same, like lighting, exact marker placement and video recording tools. These discrepancies caused random errors to occur.*

As the experiment was very hands-on, students reported issues and challenges while conducting the experiments at home. They said that they were not able to do the task effectively from home because of the limited resources available there. One student noted:

> *…. I felt doing the experiment at home for this project was very difficult and we should have had better equipment to deal with the issue of working from home. I felt take-home kits or being allowed to take equipment home would have made our lives easier in terms of the project …*

Student feedback revealed that others who conducted the home-based experiment experienced some technical challenges. However, students using the Vicon system in the laboratory to conduct gait research and analysis enjoyed that way of working but did report more workload than those who conducted the experiment in the online group. That said, all students were able to be engaged actively in conducting the experiment and collecting and analysing the data either in the lab or at home.

Face-to-face learning and online learning component

Here we report on two data sets based on the students' reflective statements and qualitative survey data in both years. Students highlighted the advantages and challenges of blended learning. In particular, students valued the face-to-face interactions with teaching staff. They often established a good rapport not only with their peers but also with teaching staff. One student commented:

> *The best aspect of this course was the teacher-student relationship between us and [the course coordinator]. We gathered a lot of beneficial learning from this course, and we were able to receive constant and consistent feedback from [the course coordinator]. The theory was delivered at the expected standard.*

For some students studying remotely and not able to conduct experiments in the laboratory, interacting with their peers online did help them stay engaged and encouraged them to learn proactively. As one student stated:

> *I love the part which we learnt a lot regarding mechanical analysis, and it is pity I could not attend any of the lab session when collecting data and interact with some of the best equipment. However, I also learnt how to conduct experiments with home set-up and it is a great opportunity to work with people in different time zones.*

Students acknowledged the blended models were helpful for learning, especially as it allowed them to learn and interact with learning materials and peers in a flexible way. They were happy with their own arrangements to conduct the experiment based on their schedules, and circumstances. One group has indicated:

> *We found it quite difficult to manage our individual University and work commitments throughout this stage of the semester which was why we decided to schedule data collection and analysis over the period colliding with lockdown. Similarly, one group*

> *member underwent an unforeseen medical procedure very close to the original deadline, which was quite a stressful experience for us. Thankfully, we were granted special consideration providing us with the time needed to complete the report. Overall, we all agree we worked well together and would combine as a group for further projects in our studies.*

Other students found that blended learning enhanced instructor–student interactions, as staff were accessible for consultation and feedback. The students also indicated that this helped them understand the course content better and increase their confidence in applying course content:

> *In person tutorials and labs were fantastic, was very helpful for learning the course content and felt good applying myself to the work. There was a lot of meetings held in person and especially online in which critical feedback and advice were given for projects. Staff were very accessible for help.*

Students experienced some challenges as they lack motivation at times due to their isolation and lack of face-to-face contact. One student indicated:

> *I don't feel motivated or encouraged to work hard in this subject. I feel that despite the interesting content I don't feel connected to my teacher.*

When compared with the 2020 online-only model, students mostly found it difficult to conduct the group project from home:

> *Maybe altering the group project to be easier to do when it was moved online. It was a lot harder to organise how to collect data and results when no one was able to meet in person.*

Generally, students found the fully online learning model challenging as they were not able to meet with each other in person to work collaboratively, and the proposed workaround approach (with personal device and open-source software Kinovea for analysis) was quite restrictive in terms of conducting experiments from home. Some students found that studying remotely also negatively influenced their learning, in which they experienced lacking motivation to work hard and connect with the teaching staff.

However, they also reported that the enhanced use of technology that integrated in the online and blended learning allowed them to have regular interaction either online or in person with the instructors and peers for discussion, feedback and review of learning materials. This created new opportunities for students to use online communication tools and technologies that went beyond not only strengthening technological skills but also employability skills.

Employability skills development

We examined the students' responses to the open-ended questions and their reflective statements for 2020 and 2021 in relation to the three top essential employability skills as identified in the literature: problem-solving, teamwork, and communication.

In relation to problem-solving, students demonstrated in their reflective statements that they knew how they answer questions relating to their projects, and they were able to communicate how they developed a solution in a clear and logical manner. To illustrate, one group reported:

> *This experiment consisted of both a lab and home set-up, with the offshore group having two members living in two different cities. The more similar the set-up condition is, the more accurate and repeatable the experiment will be. Therefore, students decided to use an office chair with no armrests, no wheels, without the ability to swivel and with its seat approximately 45cm above the ground. However, our participants did not all have the same height, which leads to a problem of, while keeping their feet touching the floor, that they cannot sit at the same point on the seat – taller people may be able to sit closer to the backrest than shorter people. This factor could possibly lead to a different trunk flexion angle as a result and alter the accuracy and reliability of the yielded data.*

On teamwork, the students demonstrated that they were able to plan and prioritise workloads, keep on top of deadlines and monitor progress. They also managed to build trusted relationships within a team:

> *A Gantt Chart was designed for all group members involved in this project to ensure that there was an equal distribution of workload and a clear schedule of tasks so that all aspects of this project were met in a timely manner. All members of the team cooperated and collaborated well together during the project and completed their allocated tasks with diligence.*

On communication, the students demonstrated this by explaining how they worked together, participated in meetings and also worked out the best tools to communicate with effectively to undertake the various tasks set for them:

> *The team effectively communicated throughout the duration of this study and were considerate about the time difference for meetings and discussion. The team used Discord and Facebook Messenger for communication and wrote the report on Google Docs. In the end, the study wasn't restricted to developing our knowledge in Biomechanics but also polished other skills such as report writing and effective communication, which is essential in real world circumstances.*

Drawing on these students' reflective statements, it is clear that the enhanced use of technology within the classroom in the blended learning model provided students with an authentic experience in developing professional skills, such as teamwork, problem-solving and communication, which have been identified by employers as lacking in the recent graduates.

Discussion

Due to the pandemic, in 2020 undergraduate biomedical engineering students were forced to transition to a fully online delivery mode. As the pandemic situation improved, blended teaching and learning has become increasingly common and has changed the way in which technology has been used in teaching and learning and how the staff and student interact. Therefore, the

main objective of this study was to investigate such interaction between learning competencies and pedagogical practice in a blended learning space.

As noted in the literature (Deveci Topal, 2016; Linda & Terri, 2014; Xiao et al., 2020), when web-based materials were used and online tools, instructor-student interaction, and attitudes towards developing employability skills were examined, our students expressed a high level of satisfaction with the blended learning. Also, our findings on pre-recorded learning materials are consistent with previous studies (Bennett et al., 2020; Marie & Shannon, 2015; Olapiriyakul & Scher, 2006): educators need to consider the students' learning styles and the appropriate use of technologies to achieve better learning performance.

We also found that students who studied remotely sometimes experienced a lack of motivation and were somewhat disengaged and disconnected. Regular checking in with students to hear concerns and offering constructive advice not only helped motivate them to stay engaged, but also improved learning outcomes. These findings confirm those of Smith et al. (2018) and Jayalath and Esichaikul (2020). In addition, we found that students' motivation and satisfaction levels improved when they had a sense of control over their learning and were able to use technology effectively, as noted by Deveci Topal (2016).

This study has also identified several new findings, challenges and opportunities for blended and online learning.

Delivery and pedagogy

Students expressed greater satisfaction with the blended learning mode. This was attributed to the convenience of, and flexibility in, having both online and face-to-face activities that allowed them to communicate with the teaching team and their peers. However, a third of the students did not consider the online environment an effective learning tool and reported that this affected their ability to complete work online.

We combined various pedagogical approaches (e.g. collaborative, integrative, problem-solving, and reflecting on practice) to help students achieve learning outcomes. In the problem-based learning process, the interactions between instructor and students mainly focused on the instructors' asking questions rather than providing explanations, thereby supporting the development of students' problem-solving and critical thinking skills (Ju & Choi, 2017). The survey results revealed that, overall, students were positive about the design and organisation of the course and how the problem-based learning component was delivered.

The group project was designed for students to engage in collaborative and team activities, in which the learning process focused on their abilities to solve real-life problems in an academic context. Some students perceived the group project as challenging and were concerned about the additional work that they might need to do to keep the group afloat. To provide students with guidance and help them engage in collaborative work, we developed a suitable assessment rubric and reflective task to measure both teamwork and individual performance. This instrument ensured group members were working together and that students took responsibility for their own work (Pang et. al., 2022). Students valued this experience working as a team, interacting with their peers and staff during the data collection phase, and being able to utilise the technology to conduct experiments, which provided them with new perspectives on and approaches to

developing transferable skills. Students also benefited from having a specific reflective task, which allowed them to see their learning in a broader context.

Interaction and feedback

During the lectorials, students interacted with the content through Kahoot quizzes using their smartphones or devices, during which key concepts were explained and assessed. They valued the instant feedback provided. Students sometimes struggled with remote learning and collaborating. Hence, we created a sense of presence for our students by using synchronous and asynchronous communication tools with regular, small-group and email check-ins. Students were encouraged to schedule small group video-conferencing to discuss their progress. Staff would send weekly emails to remind students of deadlines and, sometimes, to invite students to reflect on learning activities. The blended model enhanced our student–staff interactions which, according to students, were less restrictive in organising such online meetings and helped students to achieve a better understanding of the content and greatly improved their learning.

The students were generally technology-savvy and used personal smart devices in their everyday lives. We found that our students embraced the change to blended learning, particularly in being able to use online tools and video communications to conduct meetings and facilitate participation, to learn how to manage people and teamwork remotely, and to develop strategies and planning to achieve goals.

Students' experiences and technologies

In relation to the technology used in blended learning, we found that while students appreciated that they were able to utilise the industry-standard Vicon system in the laboratory to conduct gait analysis and work together with peers, they reported some concerns in learning how to operate the Vicon System for data collection and then analyse those data using Nexus software. This was often a steep learning curve and they needed additional guidance on set-up, calibration and operation of the system to complete experiments within the time frame. We also noted some challenges faced by students who conducted the tasks at home and reported becoming lost and frustrated. Despite the steep learning curve and challenges with the enhanced use of technology in blended learning, on the whole our students demonstrated an improvement in the technology skills that further strengthened their employability skills.

Informal feedback to the course coordinator (first author) indicated that some students experienced frequent technological and logistical problems, and poor responsiveness in the LMS, but this was likely to be related to poor internet capacity especially during the submission of online assessments. Some students, therefore, required additional time to complete assessments and this caused some anxiety and frustration. To minimise these negative effects and outcomes in future, ongoing technical, personal and organizational support on these issues is needed to ensure access to, and effective use of, ICT and LMS. However, this will also ultimately rely on students' having home access to reliable internet access.

Implications, limitations and future research

Few studies have explored whether blended learning helps students to develop their professional skills. This paper reported on a particular study of blended learning for undergraduate engineering

students. The knowledge gained from this study will provide more insight into the strengths and challenges of blended learning in a course we had to redesign in the context of the coronavirus pandemic. We believe that our findings will assist others in redesigning the pedagogical methods and technology uses in providing blended (and hybrid) mode courses in the future. This study also increases understanding of students' perspectives of their experiences in the practice and effectiveness of blended learning and suggests that potential improvements in learning outcomes and in students' learning experiences can be gained from blended learning courses.

We found the laboratory component was a good way to encourage interactions between students, in studying materials, working with peers and teachers, and provided students with a practical, authentic learning experience. The group project developed in the study was to capitalise on the social interactions between students as much as possible within the constraints surrounding the course due to the pandemic. Hence, getting the balance right between achieving efficiency in online learning and reducing the social capital gained in face-to-face learning constantly needs to be assessed as technology drives efficiency and, particularly, financial imperatives in education.

It is important to acknowledge that the findings of this study are drawn from students in a second-year undergraduate engineering biomechanics course with a relatively small class size. Moreover, many of these students would have higher computer and digital skills than the students in other disciplines or courses. Therefore, the results cannot be readily generalizable to all higher-education courses, disciplines or contexts. It is important for future research to take these limitations into account and to conduct further studies with larger, more diverse samples in different learning environments and courses to increase and assess the generalizability of the findings.

Conclusions

Blended methods of learning and teaching, while having been used in educational institutions for quite some time, have been increasingly adopted in many universities around the world due to the SARS-CoV-2 pandemic to optimize resource use in terms of space and timetables on campus, while addressing public health imperatives and pandemic control requirements. This increase in use has provided researchers with a unique opportunity to assess blended (and hybrid) learning and teaching models that reflect the changing post-pandemic world of work.

This study aimed to enhance our understanding of the effectiveness of blended learning in higher education, particularly in engineering programs that are traditionally based heavily on laboratory and hands-on practical course delivery on a physical campus. In this study, we examined whether the interaction of pedagogy and technology in blended learning was instrumental in sustaining and, possibly, improving student's employability skills.

Our findings demonstrated that through a collaborative, project-based learning approach, our students were able to follow the instructions and understand the real-world problems given, then establish appropriate methods for data collection to address the research questions or hypotheses, and report potential solutions. They learnt how to build effective working relationships with peers to achieve project delivery milestones and be flexible in learning, whether in a remote location and/or on campus. They also developed abilities to communicate with others effectively using the various ICT and across time zones. This study also sheds new light on our

understanding of the use of ICT and LMS in teaching and administration. For the students to obtain the most out of their blended and online learning experience, it was important for staff to provide timely support by checking with them or provide feedback on their work.

A key challenge in any blended and online learning environment is the importance of supporting students' psychological well-being, especially if or when they experience a lack of motivation and loss of a sense of connection. Classroom experiences and social interactions and capital that complement blended learning should be explored further. Our findings on the needs and challenges faced by students in blended learning courses suggest opportunities for educators to rethink the pedagogical, course delivery and operational strategies for the implementation of future blended learning and/or hybrid learning environments.

Conflict of Interest

The author(s) disclose that they have no actual or perceived conflicts of interest. The authors disclose that they have not received any funding for this manuscript beyond resourcing for academic time at their respective university.

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Appendix A

Sample course experience survey questions

For each of the question below, select the response that best describe how you feel about the statement, where 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree and 5 = strongly agree.

Survey questions	Likert Scale				
	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
1. The web-based (online) materials for this course are effective in assisting my learning.	1	2	3	4	5
2. I like being able to do most of the work online for this course.	1	2	3	4	5
3. I have learned something in this course which has better prepared me for employment.	1	2	3	4	5
4. The course helped me developed my ability to work as a team member.	1	2	3	4	5
5. Overall, I am satisfied with the quality of this course.	1	2	3	4	5

In your opinion:

What are the best aspects of this course?

What aspects of this course are in most need of improvement?